

**Faculty of Humanities
Curtin University Sustainability Policy Institute**

**Streets of Clay: Design and Assessment of Sustainable
Urban and Suburban Streets**

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Doctor of philosophy
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Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

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Abstract

Since automobile use became widespread in North America, Europe, and Australia during the first two decades of the 20th century, cities and their streets have been re-shaped to adapt to the motor vehicle surge. Efforts are now underway to re-define the purpose of arterial streets and to re-design these important thoroughfares accordingly. This movement has taken a variety of names, including “Livable Streets”, “Context Sensitive Streets” and “Complete Streets”. Such streets are multimodal transport links as well as places for socio-economic life and active living. This thesis presents findings from research on assessing just how “active” and “sustainable” are a set of arterial streets in five San Francisco Bay Area cities. Six streets, two re-designed as more “livable” or more “context sensitive” streets, and four more conventional arterial streets, are compared across a set of objective performance metrics and subjective assessments from street users and businesses. The analysis was grounded in a mixed methods approach. Streets were evaluated on an array of quantitative measures, as well as the results of six street user focus groups and surveys of 716 street users and local businesses. An important outcome of the research is a framework or model for influences on and supports for street activity and sustainability. Thesis findings affirm the importance to communities of multi-purpose street environments. Thesis results show that arterial streets can be re-designed to engender activity and promote sustainability. This research confirmed the importance of providing space on arterial streets for pedestrians, cyclists, and transit users. This thesis represents a significant extension of the knowledge in the field of what constitutes a more sustainable arterial street environment. The assessment framework integrates a far wider range of research disciplines and concerns than previously evidenced in the literature. As such it may provide policy-makers with a better understanding and basis on which to pursue further arterial street re-designs in similar contexts to those of the six streets I studied in this research.

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CHAPTER 1

INTRODUCTION

Preface

The quality of our streets bears directly on the quality of our own lives and the lives of our communities. As urban design scholar and practitioner, Allan Jacobs (1994) observed:

If we can develop and design streets so that they are wonderful, fulfilling places to be, community-building places, attractive public places for all people of cities and neighborhoods, then we will have successfully designed about one-third of the city directly and will have had an immense impact on the rest (p.6).

This dissertation examines how street design promotes or discourages active, sustainable communities. The examination takes place along segments of six arterial streets located in and between San Francisco and San Jose, California. As described in this and the following chapter, interest in more active, sustainable streets and communities is an important part of the larger movement toward more livable and sustainable cities.

Overview and Context

I became interested in this topic while serving as the Chief Transportation Official for Palo Alto, California, a city located roughly midway between the larger cities of San Francisco and San Jose. During my tenure with Palo Alto (1999 to 2005), our department worked with consultants to create plans for the re-design of two arterial street corridors. The intent of both plans was to foster more walking, cycling, and public transport use, as well as create better tree canopy, and thus contribute to a more active, sustainable community.

Streets can be active in the sense of supporting travel by foot or on bicycle, including walk access trips to public transport. They can also offer opportunities for activities that are not as “physical”, such as people watching, conversing with friends, or window-shopping. All of these pursuits create interest and animate streets. Streets can also become more sustainable when they endow communities with lively, interesting *milleux*. These settings stimulate the senses in a variety of ways or, alternatively, foster contemplation. An active street is one in which people encounter

other people. In all these ways, such streets can create social and cultural capital. Street activity is a necessary, but not a sufficient, condition for street sustainability.

There are other, even more apparent ways for streets to move toward sustainability. Streets that are more sustainable favor travel modes that are low- or zero-polluting and energy-efficient. They also provide space for nature and its curative effects in the form of permeable surface areas, including in the planting strip between curb and sidewalk and in street medians, as well as tree canopy along both. In addition, streets can be important engines of commerce, creating economic value while fostering social and cultural sustainability.

Schiller, Bruun, and Kenworthy (2010) include the foregoing as attributes of sustainable transport. To be sustainable, transport must do the following:

Meet basic access and mobility needs in ways that do not degrade the environment; not deplete the resource base on which it is dependent; serve multiple economic and environmental goals; maximize efficiency in overall resource utilization; improve or maintain access to employment, goods, and services while shortening trip lengths and/or reduce the need to travel; and enhance the livability and human qualities of urban regions (p. 2).

Active, sustainable streets that meet these criteria are essential for creating cities and regions that will stand the test of time. In doing so, these streets meet an intergenerational responsibility to fulfill environmental, economic and socio-cultural needs of the present and for future generations.

A number of distinguished writers have expressed the importance of sustainable streets, transport, and cities over many years, even before the term sustainability became part of the wider lexicon. Jane Jacobs (1961), writing in the midst of the post-World War II surge in what she termed “erosion” of cities by automobiles, was an intellectual pioneer in the call for “popular and interesting streets” (p. 364). Fundamentally, she argued, an urban environment of diversity and density produced the conditions in which such streets evolved (pp. 152-221). Reversing the erosion of the city by the motor vehicle called for “attrition tactics”, such as widening sidewalks, as well as planting trees along them, as “automatically this would narrow the vehicular roadbed” (p. 364). As artfully stated by Jacobs in 1961, pre-figuring the invention of “traffic calming”:

Attrition of automobiles operates by making conditions *less* convenient for cars. Attrition as a steady, gradual process (something that does not now

exist) would steadily decrease the numbers of persons using private automobiles in a city. If properly carried out ... attrition would decrease the need for cars simultaneously with decreasing convenience for cars, much as, in reverse, erosion increases the need for cars simultaneously with increasing the convenience for cars What sort of tactics are suitable to a strategy of attrition of automobiles by cities? ... Tactics are suitable which give room to other necessary and desired city uses that happen to be in competition with automobile traffic needs (p. 363).

The imperative for streets described by Jane Jacobs has come about because of the relatively recent and rapid evolution of a majority of the world's cities into auto-oriented places designed increasingly to accommodate the dominant transport technology: the motorcar and truck.¹ Historically, going back thousands of years before the industrial revolution, city streets were the arteries of "walking cities", places in which nearly everyone walked regularly and where "streets were usually crowded with pedestrians" (Crawford, 2002, p. 55). As Newman and Kenworthy (1999) point out, humanity's urban settlements were typically compact, only five kilometers or about three miles across to serve average walk trip times of half an hour (p. 28). Social interaction (spontaneous or planned) was a normal part of every city dweller's everyday life. These historical cities provided, according to Safdie (1997), "intense and active meeting places for commerce, the exchange of ideas, worship, and recreation" (p. 12).

While they engendered an active social life, the streets of these walking cities were not always narrow ways. In cultures that used teams of draft horses or mules to haul goods and materials, there was a need for ample street space to back up and turn around (Crawford, 2002, p. 56). In the West, the Roman towns and cities featured two principal axes: the east-west processional road, *Decumanus Maximus* and the main north-south road, *Cardo Maximus* (L. Adkins & R.A. Adkins, 1998, p.131).² Augustus decreed in 15 BC a standard width of 40 feet or 12.2 meters for the *Decumanus Maximus* and 20 feet or 6.1 meters for the *Cardo Maximus* (Southworth & Ben-Joseph, 2003, pp. 17-18). This was the walking city precursor of an arterial

¹ The motorization of non-OECD countries is proceeding so rapidly that they are expected account for 56% of the world's motor vehicle fleet by 2030, up from 24% in 2002. China alone is projected to have 390 million motor vehicles by 2030, twenty times more than in 2002 (Dargay, Gateely, & Sommer, 2007).

² In pre-Roman times, an Etruscan auger would take astrological sightings before laying out these axes (L. Adkins & R. Adkins, 1998, p. 131).

street system. The Romans standardized provision of street width minima and the elevated sidewalk to create the prototypical modern street design. These sidewalks, usually built on both sides of the street, accounted for up to one-half of the total street width (Southworth & Ben-Joseph, pp. 18-19). The walking city coped with growth through increased density and a greater amount of land use mix (Schiller et al, 2010, p. 25). Slow modes, walking supplemented by animal power to pull wagons and coaches at speeds of about five kilometers or three miles an hour, prevailed. Cities evolved to suit pedestrian form and scale.

This pedestrian-focused city form began to change in the West from about the middle of the 19th Century. The steam train appeared in cities as a public transport mode at about the same time as did horse-drawn trams on wooden tracks. The electric train, which tripled urban travel speed to 15 kilometers or 9 miles an hour, then superseded these earlier transit modes. This development meant that cities could now grow outward as well as upward. Nevertheless, growth in this new city form, the “transit city”, depended on pedestrian access to public transport stops. While the city spread out along transit corridors, high density, mixed-use urban forms still prevailed (Schiller et al., 2010, p. 26). In effect, the transit city preserved many of the virtues of the walking city, but quickened the pace of urban travel, while stretching its form along linear corridors outward from the center. Public transport did not disrupt the social fabric of cities. As Schiller et al. (2010) observed, “transit, by its nature, involves mixing people together in shared space and is an important factor in helping to shape social relations” (p. 27).

Although the walking city and the transit city also had their environmental problems, including coping with manure and urine deposited by draft animals (Gordon, 1991, p.8), they were active, lively places where much of the social and commercial life of communities took place on and along the streets. By 1940, however, automobile cities and suburbs emerged to change fundamentally urban form and urban streets (Newman & Kenworthy, 1999; Crawford, 2002; Schiller et al., 2010). In the “automobile city” that began to emerge in North America just before World War II and came into full bloom in the post-war economic boom, urban growth was uncoupled from pedestrian requirements and did not depend on access to public transport. Instead, development could take place along any street or highway. In practice, this change meant the filling in of areas between public transport corridors and a vast extension of the urban edge (Schiller et al., 2010). At the same

time, the new residential and commercial buildings could “turn their backs to the street while ignoring the possibility of street life” (Crawford, 2002, p. 64). A car journey of half an hour, traversing as much as fifty kilometers or thirty-one miles, extended urban development far out into the hinterland (Newman & Kenworthy, 1999, pp. 31-32). Urban and suburban streets increasingly became traffic conduits. Street uses that did not pertain to motor vehicles, commercial as well as social activities, retreated to the margins, literally and figuratively, or simply disappeared.

Arterial streets, the focus of this research, have been in the tidal flats for this extended, rising inundation of urban and suburban life by the motor vehicle tide. These streets have figuratively groaned under the sheer weight in numbers of big, motorized metal objects demanding movement and parking space. While the automobile has been busy reshaping the street and its function, there remain enduring, powerful human needs for community that were met manifestly on streets for most of humanity’s urban history. These needs still exist, despite their having been “swept under the asphalt” by the rising motor vehicle flood.

In their landmark study of residential streets in San Francisco written twenty years after the generative work of Jane Jacobs, Appleyard, D., Gerson, M. S., and Lintell, M. (1981) took up the call for more attention to the social and human value of streets. They argued that, unabated, the inundation of motor vehicle traffic threatened to overwhelm streets as places of “personal and social meaning” (p. 9). Automobile use had the potential to sever social ties on streets. By attending to the conditions that wove streets into the fabric of a community, cities could affirm human values. For Appleyard and his colleagues, the street condition that most threatened these values was excessive motor vehicle traffic. While his work and the maps and diagrams associated with it had a beneficial impact on urban planning thought, they did not seem to change the standard approach to transport planning.

For Vuchic (1999), over-reliance on the car and lack of diversity in travel choices created “pressures for wider streets and more parking space” (p. 10). Livable cities required balanced transportation systems, including walking and public transport, that were “functionally integrated with other activities and services” (p. xix). In a similar vein, Newman and Kenworthy (1999) called for an end to “automobile dependence” through transport that was grounded in economic efficiency, environmental responsibility, social equity, and human livability (pp. 41-42).

Research into active, sustainable streets is part of the quest for a more comprehensive understanding of what makes our cities and regions livable. The street provides a connection to the wider world while also offering a venue for many of life's activities. This combination of linkage and community makes the study of streets both compelling and important.

Research Focus of this Dissertation

In the age of the automobile, with its overwhelming demands for vehicle movement and storage space (as shown below in Figures 1 and 2), we must ask: Can arterial streets be designed or redesigned to become economically, socially and environmentally sustainable, livable, active and attractive places for people and communities? How then to measure and achieve such an enterprise? What are the key elements in an endeavor to make arterial streets perform as both “passage and place”? What works, what does not; what is important, what is not?



Figure 1-1. Comparative Street Space Needs of Cars, Buses, and Bicycles

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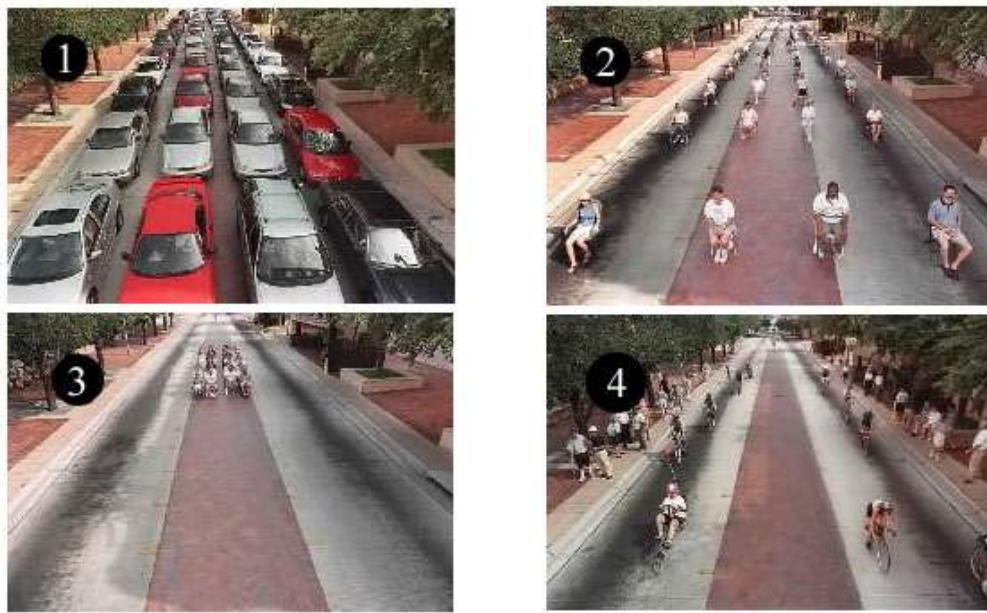


Figure 1-2. Street Space Needs of the Same 40 People in and out of Cars

Copyright 1999 by the Tampa Tribune. Photo credit to Phil Sheffield. Retrieved from the Ped Shed web site: <http://pedshed.net/?p=240>

In order to answer such a huge overarching or central research question (or questions), we must ask a series of much more detailed technical and thematic questions that cover a credible breadth and depth of knowledge in many interrelated fields and disciplines that have a bearing on arterial streets, their function, their resource use, livability and sustainability. Of necessity, finding answers to all of these questions involves research and explorations into a rich constellation of disciplines and topics ranging from sustainability, traffic engineering, transport planning, urban planning, and urban design to public health and community well-being. Therefore, the search for answers to the eight research questions frames the wide-ranging, multi-disciplinary research in this dissertation.

Thesis Argument

The thesis of this research is that it is possible to design arterial streets to be active and sustainable, both as transport routes and as venues for community life. The task is to examine street activity and sustainability. The lens used is the comparison and contrasting of six street segments, divided equally in Big City and Small City cohorts, all located within or between San Francisco and San Jose, California. An extensive literature review, information and data collection, analysis, and reflection inform this examination. Chapters 2 and 5, respectively, present the

results of the literature review and information and data analysis. My own experience as a transport planner in the San Francisco Bay Area also informed this work through my familiarity with the region's transport systems and spatial structure.

While this research is multi-disciplinary, by necessity it cannot encompass all the topics pertaining to streets. Just as transport planners delineate the spatial limits of transport studies (difficult to do in this field as, figuratively, “everything is connected to everything else”), I have had to set limits to my inquiry based on my own resource limitations (mainly time, money, energy, and focus). Therefore, this dissertation is not about – or at most only peripherally about – a number of otherwise important topics. These include, among others, the politics of street space apportionment, the cultural differences in how street space is used³, the night life of streets⁴, the effects of climate or topography on street use, and the differential effects of the street environment based on gender, racial or ethnic characteristics, or sexual orientation.

A multidisciplinary approach is a comfortable one for me, as my education and training spans several disciplines. My major work as an undergraduate was in political science. I also hold graduate degrees in urban and regional planning, transport planning, and traffic engineering. In addition, I completed coursework (but no thesis) toward a master's degree in economics. Throughout my thirty-one-year professional career in urban and regional transport planning, I have worked collaboratively with engineers, planners, architects, economists, public health specialists, and many other disciplines. I am also a part-time adjunct faculty member within Stanford University's inter-disciplinary Program on Urban Studies. This role gives me the opportunity to teach as well as learn from students across the academic spectrum.

While the hypothesis in this dissertation that street design or re-design can transform an arterial street for the better is explicit, implicit in my research approach is the requirement to lower – and not simply redistribute to other parts of the street

³ For one fine example of work in this field of inquiry, an examination of the culture of pedestrian street use in Asia, see Mateo-Babiano and Ieda, 2007.

⁴ Only 7% of daily local travel in the US takes place between the hours of 9 p.m. and 6 a.m. Since this dissertation largely concerns effects of motor vehicle traffic and other travel modes on streets and communities, the nighttime hours of reduced local travel and traffic did not present a compelling research interest. Retrieved from the US Department of Transportation, Bureau of Transportation Statistics web site:
http://www.bts.gov/publications/highlights_of_the_2001_national_household_travel_survey/html/table_a12.html

network – the overall tide of motor vehicle traffic in cities. This aim aligns with Jane Jacobs’ notion of a “steady, gradual” receding or “attrition” of the motor vehicle. This approach creates a more sustainable balance of people, nature, and automobiles in our cities. Arterial streets, like clay, have the plasticity to be molded either to suit the current motor vehicle traffic dominance (in North American cities and worldwide) or to conform to a new mold. This new mold is that of the multi-purpose, multi-modal urban arterial street suited to its urban context, while also making room for nature.

This research is not, however, a jeremiad against the automobile. I have been a car driver since my fifteenth birthday and a car owner since my eighteenth. I come from a Michigan family that has been in the automobile manufacturing business for over ninety years, mainly with the Chrysler Corporation and its predecessor, the Dodge Brothers Motor Car Company. I am convinced that the automobile and the highway network have contributed to the mobility of Americans, especially in rural areas.⁵ According to Lewis (1997), cars were also instrumental in the emancipation of women in the early decades of the twentieth century (pp. 271-272). Moreover, as an American, I recognize that the sense of freedom possible in driving (at least in more optimal conditions than peak-period traffic) is deeply consonant with America’s Jeffersonian ideals of individualism and self-reliance.⁶ Nevertheless, my view is that both the automobile and the arterial street have been badly over-tasked. This has created negative externalities that have now reached global proportions.

At times in the dissertation narrative, I will step down from the “high, hard ground” of objective analyst to the arguably more realistic role of “reflective practitioner”, to add my own perspective (Schön, 1982, p. 42). The pioneer in reflective practice thought described this role in the following memorable terms:

When a practitioner reflects in and on his practice, the possible objects of his reflection are as varied as the kinds of phenomena before him and the system of knowing-in-practice which he brings to them. He may reflect on the tacit norms and appreciations, which underlie a judgment, or on the strategies and theories implicit in a pattern of behavior. He may reflect on the feeling for a

⁵ One example was rural Iowa in the late 19th and early 20th century, where despite an extensive network of rail lines and the fact that “few farms were more than six or eight miles from a depot, rain made travel to the station impossible” (Lewis, 1997, p. 6).

⁶ See Ellis (1998) for an excellent examination of Jefferson’s libertarian outlook and its resonance with Americans to the present day.

situation which has led him to adopt a particular course of action, on the way in which he has framed the problem he is trying to solve, or on the role he has constructed for himself within a larger institutional context (Schön, 1982, p. 42).

Ulrich (2000) amplified the notion of reflective practice to explore its roots in a functioning civil society. Practitioners in such a society need to recognize the competence of non-specialists to speak authoritatively about their own experiences and values. Thus, there is ample scope for both professional transport planners like myself, as well as rank-and-file street users, to express subjective judgments about streets and their effects.

Research Questions

In the course of this work, I have sought answers to eight research questions, organized into three themes: Active streets, Street design and street function, and Sustainable streets. The questions are as follows:

"Active" streets.

1. What are "active" streets and how can "activity" on streets be measured?
2. To what extent does continuous street (building) frontage contribute to "active" streets and, if so, how can its contribution be measured?

Street design and street function.

3. To what extent does street design (geometry, partitioning of space) affect street use and, if so, how?
4. What are "complete streets" and how can "completeness" be measured?
5. To what extent does dedicated space for pedestrians, cyclists, and public transport users contribute to the amount of walking, bicycling, and public transport use along streets?
6. What is the relationship, if any, between "space for nature" and the transport and other functions of streets?
7. How does a street's aesthetic appeal affect street use, if at all?

"Sustainable" streets.

8. How can the "sustainability" of urban commercial streets be assessed?

In the process of reflecting on and answering these questions, this research intends to contribute new knowledge to the scholarly literature on active, sustainable streets. Of course, no quest for knowledge carried on at the complicated intersection of the physical and the social in which the study of streets is located can ever settle

all questions definitively. Still, there is much light to be shed in many areas not yet well illuminated in this emerging field for scholarly endeavor. Understanding more about these areas is thus a worthwhile, reachable goal.

Study Approach

The approach taken in this research is a 1:2 compare-and-contrast study of two exemplary streets with companion pairs of comparison or control streets. The exemplary streets represent the ideal-types of either completeness or context sensitivity, in the first instance in a larger city and in the second a smaller city setting. Each pair of control streets share some of the characteristics of the exemplary street, both in function and setting, but lack the design elements that set the latter street apart from them. The research also relies on a mixed-methods approach that combines quantitative and qualitative information, along with primary and secondary data, woven into a scholarly mosaic.

Organization of the Dissertation

This dissertation comprises seven chapters. Chapter 2, the Literature Review, is an exploration of the wide array of scholarly literature and literature from practice that relate to active, sustainable streets and their communities. Chapter 3, Methodology, lays out the research methods, protocols, and nature of the data collected and compiled. Chapter 4, An Anatomy of Six Streets, describes each of the street segments studied. This description includes information on the history, function, design, environs, and use of each street. Chapter 5, Findings, presents research results in three parts: across the sample of streets, along a range of street characteristics, and holistically. Chapter 6, Conclusion: Expectations, Results, and Implications for Public Policy, discusses expectations, outcomes, and implications for public policy. Chapter 7, Summary: Research Questions Re-visited, Contributions to New Knowledge, and Guideposts for Future Research, offers answers to the central research question and the set of eight research questions presented in this initial chapter and sets guideposts pointing toward future research. The Bibliography and a set of Appendices catalog in detail all the resources used in the research.

Beginning the Investigation

Chapter 2 explores the scholarly record for clues about the nature and use of streets and what makes them more or less active and sustainable. This exploration, metaphorically, will require sailing the often-stormy seas of urban planning,

transport planning, traffic engineering, urban design, public health, and literatures of other disciplines. An important purpose of exploring these literatures is to place in context this study of six street sections within and between San Francisco and San Jose. This context is about what we know and what we need to discover about the characteristics and qualities of active, sustainable arterial streets.

CHAPTER 2

LITERATURE REVIEW

Overview and Context

I intend to summarize in the pages to follow the salient thought and research on what makes streets active and sustainable. Necessarily, this review will range beyond the limits of street rights-of-way. The street, especially the commercial arterial street, is a link to people and places far beyond a center line or the edge of one building line or another. In order to organize the review, I have posed a set of questions and sought answers to them in the work of both scholars and practitioners. These answers helped guide my own research into the nature and determinants of active, sustainable “streets of clay”.

Primary question for the literature review: what is the state of knowledge regarding “active”, “sustainable” streets?

There has been a convergence of research interest in recent years on the topic of active travel or transport by researchers in urban planning, urban design, transport planning, traffic engineering, and public health (Aytur, 2007; Brownson, Hoehner, Day, Forsyth, & Sallis, 2009; Cervero & Duncan, 2003; Corburn, 2009; Ewing, 2005a; Frank & Engelke, 2001; Handy, Boarnet, Ewing, & Killingsworth, 2002; Hoehner, Brennan, Brownson, Handy, & Killingsworth, 2003; Killingsworth, De Nazelle, & Bell, 2003; Lavizzo-Mourey & McGinnis, 2003; Moscovich, 2003; Moudon & Lee, 2003; Owen, Humpel, Leslie, Bauman, & Sallis, 2004; Rodriguez & Joo, 2004; Ross & West, 1999; Saelens, Sallis, & Frank, 2003; Sallis, Frank, Saelens, & Kraft, 2004; Shay, Spoon, & Khattak, 2003). William L. Roper of the School of Public Health, University of North Carolina at Chapel Hill, expressed the spirit of this convergence as:

the public health community ... beginning to return to its roots, once again partnering with architects, planners and engineers to better understand how to build healthier communities and lifestyles (as cited in National Center for Bicycle and Walking, 2002, p. 11).

Architects, planners, urban designers, and engineers have been responding in kind. As urban planning and transportation engineering scholar Reid Ewing (2005) has observed,

Historically, urban planners have dealt strictly with travel, whereas physical activity researchers have focused on leisure-time activity. Only now are the two beginning to intersect, as the urban planning and public health fields increasingly interact (p. 72).

Handy (2005) has given a straightforward definition of active travel (or transport) as “travel from one point to another by non-motorized means” (p. 6). Ewing, Handy, Clemente, Brownson, and Winston (2006) note that streets are “where active travel to work, shop, eat out, and engage in other daily activities takes place” (p. 224). Active (or lively) streets offer opportunities for travel on foot and by bicycle, as well as afford an animated venue for social, commercial, and recreational activity (Mehta, 2006). The Danish urban designer Jan Gehl (1989) has called such streets “the largest stage in the city, and the most used” (p. 17).

While street travel on foot or by bicycle is by nature active, recreation on streets can be either active or passive, as in walking for exercise or simply sitting on a public bench or at a café table to watch people walk past. It was in this sense that the great advocate for city streets and sidewalks, Jane Jacobs (1961), characterized a lively street as one that “always has both its users and pure watchers” (p. 37). Mehta (2006), in a research study inspired by Jane Jacobs’ observation as well as research by Jan Gehl, described a lively street as one “with the presence of a number of people engaged in a variety of predominantly stationary, lingering, and sustained activities, particularly those activities that are social in nature” (p. 11).

Streets are not only arteries for circulation but also places for outdoor activities of a functional, social, or recreational nature (Gehl, 2006). The street is not only “link” and “place” (Jones, Boujenko, & Marshall, 2007), but also a “social arena” (Lillebye, 2007). Streets become lively because of people, their activities, and their interactions (Mehta, 2006).

The Brundtland Report (World Commission on Environment and Development, 1987) defined “sustainable development” as that which “meets the needs of the present without compromising the ability of future generations to meet their own needs” (p. 43). Research interest in sustainable cities (Newman & Kenworthy, 1999) includes a focus on sustainable transport or sustainable mobility (Gudmundsson, 2004; Litman, 2005; Litman & Burwell, 2006) and sustainable streets (Bevan, McKenzie, Sklenar, & Derry, 2007; Greenberg, 2008).

The Vancouver Conference, “Toward Sustainable Transportation”, hosted by the Organisation for Economic Cooperation and Development (OECD) and the

Government of Canada in 1996, provided an important impetus to policy development for sustainable transport (OECD, 1996). In 2000, an OECD conference in Vienna adopted Guidelines on Environmentally Sustainable Transport, defined as transportation that “does not endanger public health or ecosystems and meets needs for access consistent with (a) use of renewable resources below their rates of regeneration, and (b) use of non-renewable resources below the rates of development of renewable substitutes” (OECD, 2000, p. 17).

Newman and Kenworthy (1999) have characterized sustainability in cities as “the reduction of the city’s use of natural resources and production of wastes, while simultaneously improving its livability, so that it can better fit within the capacities of local, regional, and global ecosystems” (p. 7). For them, city sustainability is “not only about reducing metabolic flows (resource inputs and waste outputs); it must also be about increasing human livability (social amenity, health, and well-being)” (Newman & Kenworthy, 1999, p 10). In this perspective, “key techniques” for “overcoming automobile dependence” and moving toward sustainable transport in a sustainable city are “quality transit, bicycling, and walking” (Newman & Kenworthy, 1999, p. 144). For Greenburg (2008), sustainable streets foster increased use of least polluting (travel) modes, promote reduced motor vehicle miles of travel, and address “social public health” (p. 29). To Bevan et al. (2007), they also result in reduced energy use and “support healthy urban communities” (p. 4).

Thus, we can see that research interest in active transport and lively streets is closely related to inquiry into sustainable transport and streets. The primary question posed in this chapter is, “What is the state of knowledge regarding active, sustainable streets?” More specifically I ask, “What do we know about the nature, determinants, and effects of such streets?” This question can be distilled into the following question: “How might we define a sustainable arterial street?”

Secondary questions for the literature review.

Pursuit of an answer to the primary question of this literature review requires inquiry into a set of fifteen secondary questions. These questions, in the order they will appear in the remainder of this chapter, are as follows:

Functions of arterial streets.

1. What is the fundamental purpose and nature of arterial streets?
2. What are the transport functions of arterial streets?
3. How do arterial streets contribute to social and economic life?

Arterial streets and activity.

4. What makes arterial streets active?
5. How do active arterial streets contribute to healthy communities?

Arterial streets and sustainability.

6. What makes arterial streets “sustainable” and how do sustainable arterial streets contribute to sustainable cities?
7. How can the potential for and performance of “sustainable”, “active” arterial streets be assessed?
8. What are the ways in which to design “sustainable”, “active” arterial streets?

Arterial streets and demand for access and use.

9. What determines the demand for travel and choice of travel mode on arterial streets?
10. What determines the demand for pedestrian and bicycle travel on arterial streets?
11. What determines the demand for public transport on or adjacent to arterial streets?

Choice of access mode to arterial streets.

12. What determines the choice of access mode to public transport on or adjacent to arterial streets?

Safety and arterial streets.

13. What determines the safety of walking and cycling on arterial streets?

The theoretical basis for studying arterial streets.

14. What is the theoretical basis for the study of active, sustainable streets?

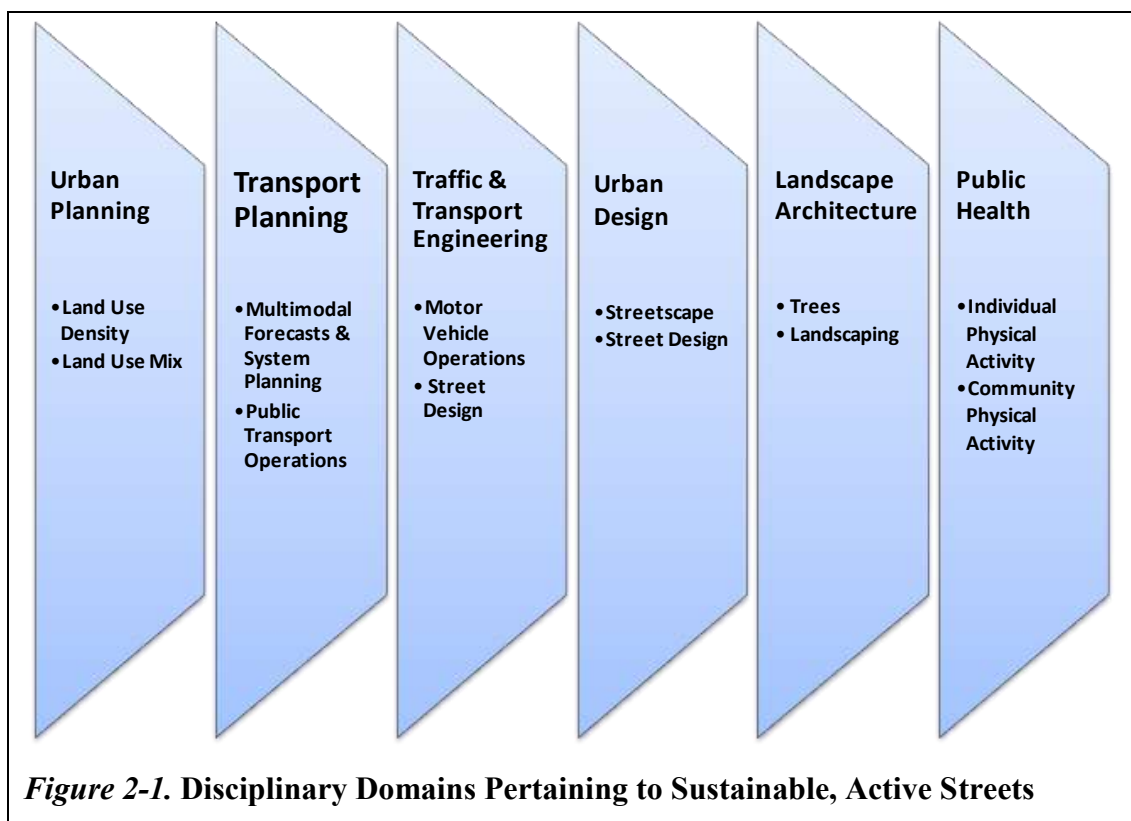
Working definition.

15. To what extent can a working definition of a “sustainable” arterial street be developed after answering the foregoing questions?

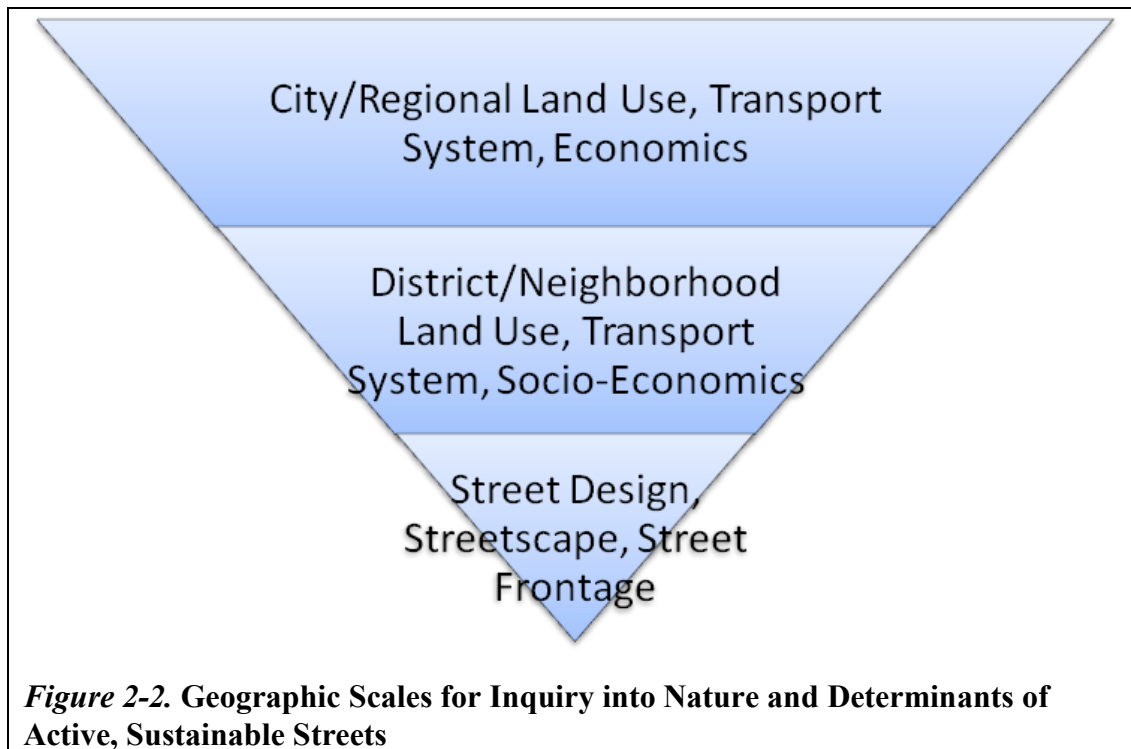
Format and approach to inquiry into the literature.

The search for answers to these questions leads to a cross-disciplinary journey into expansive bibliographic territory. Just as streets connect, albeit sometimes divide or sever neighborhoods and districts of a city (Bradbury, Tomlinson, & Millington, 2007), the study of streets and their impact joins together several scholarly neighborhoods and districts, which are often disconnected from one another in the organization of knowledge. Most of the remainder of this chapter is

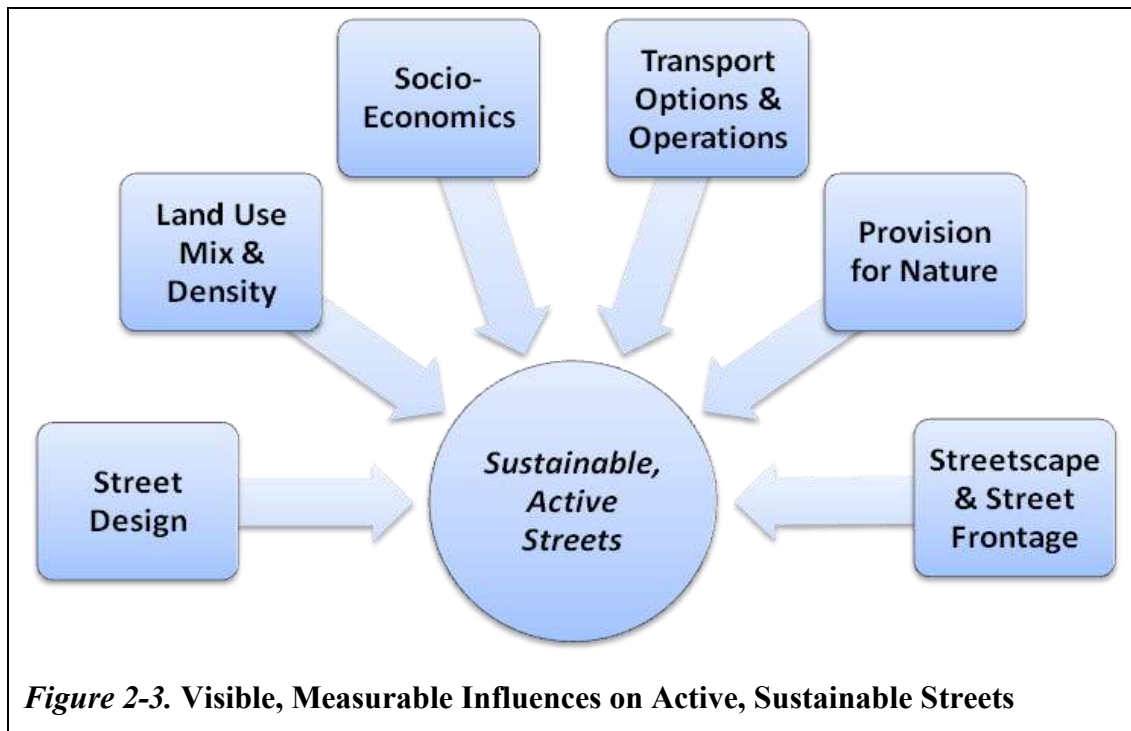
organized around the fifteen questions listed above. A concluding section considers the various ways in which the over-arching question of the state of knowledge regarding active and sustainable streets is answered in the scholarly record. This summary discussion includes consideration of how this dissertation builds upon and fills gaps in this record. The approach taken in the review of the scholarly literature reflects in microcosm the broader move to a multi-disciplinary, comprehensive, context-rich approach to transport planning (Kane & Del Mistro, 2003; Litman, 1999). As shown on Figure 1, knowledge pertaining to active, sustainable streets resides in many disciplines.



As well as being multi-disciplinary, this inquiry into the scholarly and practitioner literatures takes place on three geographic scales: citywide and regional, district and neighborhood, and street-level. The emphasis in this review is inversely proportionate to geographic scale. More attention and a tighter focus are given to research taking place closer to the apex and further from the base of the inverted pyramid displayed in Figure 2.



Pathways of inquiry into the nature and determinants of sustainable, active streets are diverse. Some of the most important are the built environment (land use, transport systems, street front), urban design (streetscape, provision for nature), socioeconomic (demographics, incomes, employment), socio-cultural (cultural norms, peer and family influences on street users), and the psychology of individuals (perceived comfort, safety, and satisfaction of street users). While the literature on all these pathways will be explored in this chapter, the focus will be on the visible and quantifiable aspects of streets. Figure 3 shows these observable influences on active, sustainable streets.



The literature reviewed in this chapter is almost exclusively based on studies conducted in the developed world, mostly in North America, Europe, and Oceania. There are two reasons for this. The relevant literature is focused on these regions and the case studies undertaken for the research are all based in California. As such, it is important to understand the knowledge generated in similar environments.

The Nature and Purpose of Streets

Question 1: what is the fundamental purpose and nature of arterial streets?

Streets.

Streets have existed virtually since the appearance of human settlements. The first streets, built of limestone and raised above the ground, may have appeared at Khirokitia in what is now Cyprus some eight thousand years ago. The first sidewalks, or pavement dedicated to pedestrians as a street design feature, may have been built at Kültepe in Asia Minor about four thousand years ago (Kostof, 1992, pp. 176-177). Ancient Rome had three types of streets: *itinera* exclusively for pedestrians, *actus* for a single cart at a time, and *viae* for two carts, side-by-side (Gunnarsson, 2004, p. 1).

Gehl (2006) points out that “in the entire history of human settlement, streets and squares have been the basic elements around which all cities were organized”. Thus, they “constitute the very essence of the phenomenon ‘city’”. Streets are “based

on the linear pattern of human movement” and squares on “the eye’s ability to survey an area” (Gehl, 2006, p. 89). In the words of the noted British scholar of streets and street patterns, Stephen Marshall (2009), “the arrangement of cities in streets is not just about physical circulation, but is inextricable from the very concept of a city” (p. 111).

Streets naturally remain a notable feature of contemporary cities. Beven et al. (2007), for example, estimate that about two-fifths of the area of the city of Seattle, Washington, is in street rights-of-way (p. 3). The American urban design scholar Allan Jacobs (1993) asserts that, “in the United States, from 25 to 35 percent of a city’s developed land is likely to be in public right-of-way, mostly in streets” (p. 6). As of 2008, there were more than one million miles (1.6 million kilometers) of urban surface streets (excluding grade separated freeways and motorways) in the United States. Arterial streets comprised 170,297 miles (274,008 kilometers) of these miles and the remaining 866,720 miles (1,394,552 kilometers) consisted of collector and local streets (U.S. Federal Highway Administration [FHWA], 2009, Table HM-220).

There have been many attempts to define the terms “street” and “arterial street”. A standard, abridged dictionary definition of the former is as follows (*Merriam-Webster Online Dictionary*, n.d.):

- a: a thoroughfare especially in a city, town, or village that is wider than an alley or lane and that usually includes sidewalks;
- b: the part of a street reserved for vehicles; and
- c: a thoroughfare with abutting property.

Etymology: Middle English *strete*, from Old English *stræt*, from Late Latin *strata* paved road, from Latin, feminine of *stratus*, past participle

Date: before 12th century.

It is interesting that even this set of basic definitions contains within it ambiguity about the nature of the street. Does it include abutting properties and sidewalks, as well as the travel way for vehicles? Does it consist of only the travel way for vehicles? Of these three definitions, only one explicitly includes abutting buildings with their doorways from which street users appear or disappear from view. Pedestrian ways are explicitly included in one definition and implicitly in another. Vehicles are included in all three, one explicitly and two implicitly.

An influential US traffic and transportation engineering manual (American Association of State Highway and Transportation Officials [AASHTO], 2004) defines the “Local Urban Street” as “a public roadway for vehicular travel including public transit ... refers to the entire area within the right-of-way. The street also serves pedestrian and bicycle traffic and usually accommodates public utility facilities within the right-of-way” (p. 389).

This definition encompasses the area between the building frontage on either side of the entire space provided for motor vehicle movement and parking, pedestrian movement and dwelling (standing or sitting at a bus stop waiting to board or standing on the sidewalk next to a friend while engaged in a conversation), bicycle movement and parking, and public transport vehicle movement and dwelling (as at a bus or rail passenger stop while passengers board and alight). Street furniture (benches, rubbish containers, signs, etc.), public art, and landscaping between the curb and the building frontage and within the street median, if any, are also included.

The conflict around hierarchy of street use is an important theme in scholarship on the evolution of streets, as well as in the professional cultures of transportation and traffic engineering, urban planning, and urban design (Brown, 2006; Hebbert, 2005; Hess, 2009; Lillebye, 2007; Marshall, 2005; McShane, 1994). In the words of one of the most celebrated students of the street, Donald Appleyard (1987): “The streets have always been scenes of conflict. They are and always have been public property, but power over them is ambiguous, for the street has an open and easily changeable nature” (p. 9). Similarly, from his generative work on the effects of street traffic on residential life (Appleyard, et al., 1981), Appleyard contends: “The street has always been the scene of ... conflict, between living and access, between resident and traveler, between street life and the threat of death” (p. 1).

For Anderson (1986), streets have an intermediate position in cities, towns, and villages, “intersecting public and private, individual and society, movement and place” (p. 1). Rykwert (1986) describes them as “human movement institutionalized”. As defined by Kostof (1992), streets are “human intercourse institutionalized” (p. 189). Marshall (2005) sees them as having “multiple personalities ... a variety of different characteristics that are present simultaneously” (p. 23). In the words of David Engwicht (1999), the Australian cultural planner, activist and advocate of traffic calming, streets provide “a dual space for both

movement and exchange” (p. 19). Gehl and Gemzoe (2003) have pointed to three roles for streets and squares: “meeting place, marketplace, and traffic space” (pp. 97-98). Marshall (2005) has observed that the street can be defined to be either “a road that happens to have an urban character, or as an urban place, that happens to serve as a right of way” (p. 22). Allan Jacobs (1993) has portrayed the street in kinetic terms: “The street is movement: to watch, to pass, movement especially of people: of fleeting forms and faces, changing patterns and dress” (p. 4).

For Jane Jacobs (1961), “streets provide the principal visual scenes in cities” (p. 378). Similarly, in the conceptual framework of the urban design theorist Kevin Lynch (1960), streets are “paths” or “channels along which the observer occasionally, or potentially moves”; moreover, “people observe the city while moving through it” (p. 47). Allan Jacobs (1993) also sees streets as “places of social and commercial encounter and exchange” that “allow people to be outside” (p. 4). Rapoport (1987) noted that streets are “more or less narrow, linear spaces lined by buildings found in settlements and used for circulation and, sometimes, other activities” (p. 81). For Moule and Polyzoides (1994), streets are “communal rooms and passages” (p. xxii).

Jane Jacobs (1961), in her influential critique of modernist American city planning described streets and their sidewalks as “the main public places of a city ... its most vital organs” (p. 29). Their “fundamental task” was keeping a city safe, largely, in her famous phrase, by people on them providing “eyes upon the street” (pp. 30, 35). Beyond catering to the demand for movement and providing surveillance, Mehta (2006) observes that streets may also be “a place for shopping, play, relaxation, and social interaction” (p. 170). To Lillebye (2007), streets function as “an element of urban form, a communal arena, a cultural arena, and a social arena” (p. 2).

The “space syntax” scholars Jiang and Liu (2009) define a street simply as “a linear geographic entity that stretches in two-dimensional space and is often given a unique name” (p. 1,120). The Web site for the Global Transport Knowledge Partnership (2010) contains a more comprehensive, yet also concise, definition: “A street is a multi-functional space, providing enclosure and activity as well as movement” (Definitions section, ¶1). The same Web site lists street functions in similarly comprehensive, yet more detailed, terms: “circulation, for vehicles and pedestrians; access to buildings, and the provision of light and ventilation; routes for

utilities; storage spaces, especially for vehicles; public spaces for human interaction and sociability” (Context and Policies section, ¶1). In summary: “Most streets perform all of these functions, and often the balance between them will vary along the length of the street” (Global Transport Knowledge Partnership, 2010, Context and Policies section, ¶2).

Grava (2003) argues that streets began simply as “linear spaces left between building lines”, where urban life in all its variety unfolded in these animated ways: “People, carts, and animals used the same channels, mixed freely, and were all impeded by the many activities that spilled out onto the street ... peddlers, vendors of food, purveyors of various services, entertainers, musicians, preachers, children, thieves, and beggars” (pp. 15-16). For Marshall (2003), the street is “an important integrating component ... not only as a physical movement channel and built form but also as a public space, a place of cultural identity, setting for social and economic activity, and indeed contributor to urban equity and sustainability” (p. 771). Marshall (2003) concludes that, “the street is fundamentally a means of organizing activities around a pattern of circulation” (p. 772). In the view of Kostas (1992), “traffic, the exchange of goods, and social exchange and communication” are the traditional purposes of streets (p. 189).

Brindle (2003), an Australian traffic engineer and scholar, differentiates between “functions” and “uses or attributes” of roads or streets. The movement functions include circulation and access by the various transport modes. The terminal functions consist of vehicle parking and loading/unloading of goods. The amenity and social functions include use of adjacent land and buildings, a place for social interaction, and a place for leisure and recreational activities such as strolling or jogging (Brindle, 2003, p. 3.1.3). The uses or attributes of a road or street include accommodation of public service utilities, being an essential part of the urban drainage system, and as “a major component in creating the visual image of the area through which it passes” (Brindle, 2003, p. 3.1.4).

Sorting out and separating uses or activities within the street space has been an ongoing and sometimes contentious process (Hawkes & Sheridan, 2009a,b,c; J. Jacobs, 1961; Jones et al., 2007a; Kostof, 1992; Lillebye, 2007; McShane, 1994). Indeed, contemporary advocates of “shared space” argue that in many circumstances these uses should be left largely to sort themselves out as pedestrians, cyclists and drivers negotiate right-of-way by relying on eye contact with one another as well as

on other visual and tactile cues provided to them by means of urban design (Hamilton-Baille, 2004, 2008; Clarke, Hamilton-Baille, and Monderman, 2006; Passmore, 2005).

Plowright and Marshall (2004) argue that there is no clear conception of what is an arterial street (p. 1). The difficulty in defining arterial streets with precision is illustrated in the description given to urban arterials in the authoritative street design manual used by traffic and transportation engineers in the US (AASHTO, 2004): “Urban arterials carry large traffic volumes within and through urban areas. Their design varies from freeways with fully controlled access to two-lane streets” (p. 469).

Marshall (2005) defines “arterial route” as “a constitutionally defined type of route, forming the upper-most tier in an arterial network, such that the set of arterials forms a complete contiguous network An arterial may take different forms (e.g. arterial road, arterial street, etc.)” (p. 291). The term “arterial” also has a meaning beyond that of a street. *Merriam-Webster Online Dictionary* (n.d.) lists the street usage as secondary:

Main Entry: ar·te·ri·al

Function: *adjective*

Date: 15th century

1 a: of or relating to an artery b: relating to or being the bright red blood present in most arteries that has been oxygenated in lungs or gills

2: of, relating to, or constituting through traffic

Marshall, Jones, and Plowright (2004) have defined the arterial street in more comprehensive terms: “a multifunctional urban street combining through movement and other urban functions, where the through movement function has relatively high strategic significance” (p. 28). The “Network City” framework for integrated transport and urban planning in Perth, Western Australia differentiates between arterial roads dedicated to traffic movement across the metropolitan area and “sub arterial roads” or “activity corridors” on which traffic is managed to provide “safer, more attractive pedestrian environments” (Curtis, 2008, p. 105).

Arterial streets have been classified as urban, suburban, rural, major, minor, principal, regional, or strategic, depending on their function and location within the street and urban/regional systems (AASHTO, 2004, pp. 10-12; Transportation Research Board [TRB], 2000, pp. 10-5-10-7; Zegeer, Institute of Transportation

Engineers [ITE], 1999, pp. 211-212). *A Policy on Geometric Design of Highways and Streets* (AASHTO, 2004) notes that while the job of Urban Principal Arterials is to “carry most of the trips entering and leaving the urban area, as well as most through movement bypassing the central city”, Urban Minor Arterials interconnect with and augment the system of Urban Principal Arterials, accommodate “trips of moderate length at a somewhat lower level of travel mobility” and “to geographic areas smaller than principal arterials” (p. 11). This uneasy foundation for the taxonomy of arterial streets is in contrast to a professional culture in traffic engineering that strives toward “application of technology and scientific principles” (Pline, ITE, 1999, p. 1).

As aspirations, if not always realities, Svensson (2004b) tasks arterial streets with being “multimodal”, “multifunctional”, “multi-dimensional”, and as an “urban place, people-oriented, sustainable” (p. 18). d’Ieteren, Morelle, and Hecq (2002) describe arterial streets as multifunctional in serving different types of users, pedestrians as well as vehicle occupants, cars and trucks as well as buses and bicycles. They have a transport role in connecting different parts or quarters of the city, an access role in connecting the street to the land uses it abuts, and an urban role as a public space “important to the city’s economy” (d’Ieteren, et al., 2002, p. 11). This description by d’Ieteren, et al. reflects the three geographic levels at which research into streets operate (Figure 2).

Marshall, et al. (2004) see an interplay between “the street as an artery”, [thus] “a part of the street system as a whole” and the arterial street as “an urban place within the urban area as a whole” (p. 3). As Plowright and Marshall (2004) see it, arterial streets are “not only corridors, but also ‘rooms’ in which much of city living happens” (p. 1). Exploring whether and how these aspirations are met is an important focus of the research undertaken for this dissertation.

Calthorpe (1993) differentiates arterial streets, which should convey through traffic, from “commercial” streets, which are “located in the center of the core commercial areas ... designed to accommodate pedestrians, slow traffic, provide on-street parking, and create pleasant shopping environments” (pp. 88-89). In this vision, commercial streets are the embodiment or re-incarnation of the Main Street ideal, which is “part of the “iconography of American life” (*Wikipedia: The Free Encyclopedia*, n.d., American Cultural Usage section, ¶4). In catering for through traffic, this conception of the arterial street is also strikingly similar to the

conventional traffic engineering description of Minor or Major arterial streets, on which service to motor vehicle traffic movement is either a major or primary consideration, respectively (Brindle, 2003, p. 3.1.17).

The street in all its complexity and however it is defined serves several core functions. Marshall (2003) expresses the teleology of the street in these terms: “The street essentially embodies three dimensions in a single package: as a transport route or artery for through movement; ... as a public space, where a variety of human activities take place; and ... as a built frontage” (p. 771). Again, we see the conceptualization or definition of a street reflecting the three geographic scales depicted in Figure 2.

How street space is, could, and should be allocated among these functions or dimensions, has long been the subject of lively debate and dispute (Appleyard, 1987; Kostof, 1992). Jane Jacobs (1961) described the competition for the street in this way: “Vehicles compete with each other for space and for convenience of their arrangements. They also compete with other uses for space and convenience” (p. 349).

In some ways the competition for allocation of street functions is a debate about the city or region-wide functions of a street, the district or neighborhood role of the street, and the micro-scale function of street frontage and streetscape. Such competing demands are inherently difficult to meet and give rise to a huge body of research across many disciplines. To add further complexity, Hawkes and Sheridan (2009c) have even contended that streets are de facto “land banks” and, as such, are “the ultimate untapped urban resource ... that is waiting to be cashed in”, implying the need for a fundamental re-allocation of street space (The Great Opportunity section, ¶1). The street, that most ordinary public utility, is not only useful, but also complex and imbued with potential. Inquiry into whether and to what extent this potential is fulfilled is central to the research in this dissertation and much of the scholarly work discussed in this chapter.

Street networks.

Moudon (1987) noted that streets can be considered either as “individual spaces” or as a network or part of a network “linking urban activities in time as well as in space” (p. 13). Marshall (2005) has written that the “road network is effectively like a kit of parts, chiefly conceptualized as links and nodes (junctions)” (p. 29). Further, “these relate fundamentally to paths of movement: if there is no movement,

there is no street” (Marshall, 2005, p. 107). Siggers (2003) describes the arterial road network as “a major communications layer that spans between an urban area’s strategic routes for movement and the distribution networks of local areas” (p. 4.3.1).

The nature of street networks, patterns, or systems influences how these are used. Street network morphology can be distilled to two types: the grid, or streets “internally and externally” connected in a broadly rectangular pattern, and the tributary, streets “branching and clearly hierarchical” or “dendritic” (Brindle, p. 3.1.18, 2003; FHWA, ITE, United States Environmental Protection Agency [EPA], & Congress for the New Urbanism, 2006, p. 29). Calthorpe (1993) has argued that “simple, memorable, and direct, avoiding circuitous routes ... clear, formalized, and inter-connected street systems” abet travel on foot and bicycle by providing “the shortest and most direct path for pedestrians and bicyclists” (pp. 65). In this view, interconnected street networks distribute or disperse traffic among an array of routes rather than congesting any given street in a locality. This eases street crossing conditions for pedestrians and provides alternative movement paths for all street users, including walkers and cyclists (Calthorpe, 1993, p. 65; ITE, 1999, p. 186; FHWA, et al., 2006, p. 29; Greenberg & Dock, 2003, pp. 10-11). Ewing (ITE, 1999) observes that the main disadvantage of grid networks is that they result in more traffic on local residential streets; hybrid network designs combining features of both the grid and the tributary have been developed to mitigate this effect (p. 187).

The grid network has a long lineage. Gunnarsson (2004) has dated regular street patterns to 2,500 BC in Kahun, a town in ancient Egypt built for pyramid workers. The ancient Greek theorist of town planning, Hippodamus, introduced a grid network in the city of Miletus in the 5th Century BC (Gunnarsson, 2004, p. 1).

Brindle (2003) points out that even the grid network contains preferred routes and thus a street hierarchy, because traffic sorts itself and some streets take on a greater traffic role than others, due to factors such as “intersection priorities, speed limits, and turn conditions and controls” (p. 3.1.10). This supposition that there is a hierarchy in all street networks, grid or otherwise, has some support in topological analysis conducted within the space syntax framework.

Bafna (2003) writes that spatial syntax “investigates the relationship between human societies and space from the perspective of a general theory of inhabited space in all its diverse forms” (p. 17). In this investigation, space is “re-described in an abstracted format focusing on its topology” (Bafna, 2003, pp. 38-39). For Penn

(2003) space syntax analysis “represents and quantifies aspects of spatial pattern” (p. 31). Jiang (2007) studied 46 street networks, mainly in the US, to find that for any given street network 80% of the streets have “length or degree” shorter than the network average, 20% are longer, and 1% of streets “form the backbone of the street network” to constitute a “cognitive map of the urban street network”. Thus, by conjecture, “20% of streets account for 80% of traffic flow” (Jiang, 2007, p. 655).

Arterial streets as “links” and “places”.

Wahl, Hyden, and Svensson (2007) describe the complex, multifunctional environment of the arterial street in these binary terms: “as a link or a place, as a transportation route or as a shopping environment, as somebody’s front yard or somebody else’s way to work” (p. 2). Jones, Roberts, and Morris (2007b), authors of a UK study of mixed-use high streets (known in the US as main streets or commercial arterials in downtowns and neighborhood centers), noted that these streets have the dual function of “links in a movement system that connects places and destinations or places in their own right” (p. xi).

Arterial streets have both an “arterial role” and an “urban place role” (Marshall et al., 2004, p. 4). Jones et al. (2007a) note that the link function of an arterial street “serves to enable users to pass through the street as quickly and conveniently as possible” and the place function “seeks to encourage users to stay as long as desirable on a street and enjoy the street’s surroundings” (pp. 20-21). The research completed for this dissertation investigates how well or how poorly these link and place functions are reconciled or balanced along sections of six arterials streets in the San Francisco Bay Area of California.

The Transport Function of Arterial Streets

Question 2: what are the transport functions of arterial streets?

Moving and dwelling between movements.

Brindle (2003) characterizes the transport, or movement, functions of arterial and other types of streets as follows: “provision for journeys by road vehicles; movement of emergency vehicles, essential services and public transport services; vehicular access to properties; pedestrian and cyclist movement; and terminal functions such as parking and loading/unloading of goods” (p. 3.1.3).

Streets are part of the transportation system, the basic structure of which includes both physical links for movement and terminals for parking (Homburger, 1996, p. 2-1). Consumers of the link function of streets include car users, pedestrians,

cyclists, bus (and rail in the case of trams and light rail transit) passengers, and goods movement providers (Jones et al., 2007a, p. 20). The Urban Arterials chapter of the standard US street and highway design manual reflects both the physical link and terminal functions of streets in sections on street width, number of travel lanes, lanes for parking, and sidewalks (AASHTO, 2004, p. xxiv).

Assessment of the performance or “level of service” of the link function is an important task in traffic engineering and transportation planning (Dowling & Reinke, 2008; Phillips & Guttenplan, 2003; TRB, 2000). Design, evaluation, and management of on-street and off-street parking facilities are other important jobs undertaken by transport planners and engineers (Smith, 1999; Levitt, 2000; Young, 1991, 2003).

Pedestrian movement is both a part of the transportation (or link) and the place functions of arterial and other streets. Pedestrians can be differentiated by the purpose of their walk. Those using the street for through movement and thus most interested in efficient travel on foot are “striders”; those using the street as a venue for window shopping, socializing, and other non-travel related purposes, thus more attracted by street amenities and interest, are “strollers” (Jones et al., 2007a, pp. 20-21).

Marshall (2003) partitions street functions into a “transport axis” and a “people axis”. Activities on the transport axis include car driving and parking, goods vehicles driving and servicing, public transport operations in transit and in layover or dwelling at stops, cycles (motorized and non-motorized) cycling and parking, and pedestrians walking “in transit from A to B” (Marshall, 2003, p. 776). There are other street and sidewalk transport devices in addition to cars, trucks, buses, trams, motorcycles, and bicycles. These include walkers, skates, skateboards, scooters, Segways and other small wheeled means of movement, “Personal Mobility Devices”, and “Electric Personal Assistive Mobility Devices” (Litman & Blair, 2010, p. 2).

Street network classification systems.

In 1910, there were only 458,000 automobiles owned in the entire United States. By 1920, there were 8,131,000. Less dramatic, yet very substantial, increases in vehicle ownership also occurred in other Western nations, including the United Kingdom, France, and Germany (McShane, 1994, p. 105). Street traffic surged in step with the rise in motor vehicle ownership. Municipalities responded by rebuilding cities - especially by widening city streets - to accommodate car traffic and

by creating a new regime of traffic control, including traffic signal lights (Cleveland, 1914), stop signs (Detroit, 1915), and uniform traffic regulations (first proposed in American City Magazine, 1916), all to be overseen by engineers engaged in traffic planning (McShane, 1994). The engineers responded in the 1920s with street classification schemes that were designed to separate higher-speed through traffic from lower-speed local traffic (Brown, 2006, pp. 16-17). According to Jones, et al., (2007a), the functional classification schemes that emerged were “primarily concerned with the movement of traffic along the street and not with the use of the street in its own right” (p. 42).

The functional classification of streets and highways for traffic engineering purposes in the US is based on several distinct travel movements or stages of a typical trip: “main movement, transition, distribution, collection, access, and termination” (AASHTO, 2004, p. 1). These movements or stages are classified hierarchically. They begin with travel on limited access freeways or motorways (main movement), then to freeway or motorway off-ramps (transition), from these to “moderate-speed” arterials or distributor facilities, then onto collector streets that penetrate neighborhoods, thence further to local access roads for direct connection to residences or other destinations, and finally to parking facilities for termination of the trip (AASHTO, 2004, p. 1).

While freeways and motorways are by definition limited access routes, for surface streets and highways there exists a travel trade-off or continuum comprised of two dimensions: mobility and access. Arterial streets are assigned the functional requirement of providing considerably more mobility (convenience and high travel speeds for through traffic); collector streets are to provide roughly equal mobility and access (direct connection to travel destinations); local streets are tasked with offering considerably more access than mobility at lower speeds (AASHTO, 2004, p. 7).

Functional classification has implications for highway and street design parameters and resultant traffic carrying capacity. These parameters include design speed (a function of horizontal and vertical alignment, lane width, intersection spacing, and other variables) and cross-section (number and type of lanes); traffic control devices (traffic signals with their signal phasing and cycle length, stop signs, roundabouts, etc.); and access management or number and usage of driveways and cross-streets (AASHTO, 2004, p. 13; Brindle, 2003, pp. 3.1.20-23; Roess, Prassas, & McShane, 1990, pp. 29-23).

Marshall et al. (2004), critics of conventional highway and street functional classification schemes, have pointed out that today “there is no place for the traditional arterial street: only arterial roads or local access streets” (p. 6). For Jones et al. (2007a) the consequence is that “the urban street has occupied an uncertain position in terms of planning and design” (p. 18). The response has been increased interest in “integrated roads” and recognition of mixed-use arterials as an important street type (Brindle, 2003, p. 3.1.20). As a result, alternative highway and street classification schemes and taxonomies have been suggested or promulgated to secure recognition for mixed-use arterial streets, along with traditional main streets and high streets, as essential parts of both the urban transport and the urban land use systems. The research conducted this dissertation feeds into this general endeavor to gain greater clarity and support for a more balanced approach toward arterial streets as both movement and social space.

Gunnarsson (2007) for example, has proposed a “living space model for classification of city space for mobility”, which is based on the desired or required amount of space for pedestrians, bicyclists, and motor vehicles (p. 35). Gunnarsson’s street classification typology consists of three principal categories: Free Foot Space exclusively for pedestrian and bicyclists, Traffic Calming Space in which pedestrians and bicyclists are given priority over motor vehicle traffic, and High Speed Transport Space for exclusive use of motor vehicles. In Venn diagram fashion, however, these categories overlap to create two additional or intermediate types of street space: one is created by the overlap between Free Foot Space and Traffic Calming Space - for example, the Dutch *woonerven* on which cars are tolerated but walkers and cyclists are given clear priority (ITE, 1999, p. 10) - and the other by the overlap between Traffic Calming and High Speed Transport Space, the situation for many city streets. These street space categories represent points on a continuum from separation through integration, then differentiation of travel modes (Gunnarsson, 2007, p. 35).

Perhaps the two most prominent among the newer schemes or taxonomies, however, are Link/Place street classification, which evolved out of the European research initiative, Arterial Streets Toward Sustainability or ARTISTS (Jones et al., 2007a; Svensson, 2004a) and the Context Zone/Thoroughfare Type framework developed by a group of American traffic engineers, transport planners, and urban designers under the auspices of ITE, the Congress for the New Urbanism, FHWA,

and the US Environmental Protection Agency [USEPA] (ITE, 2006). Each provides taxonomical space for the mixed-use street.

In the Link/Place system, street segments are cross-classified in 4x4, 5x5, and 6x6 matrices (depending on city size) by transport or link status and urban or place function categories. Street sections in a medium to large city, for example, would be categorized as having National, City, District, Neighborhood, or Local transport and urban place significance, respectively. This 5x5 matrix yields twenty-five different link-place categories, a far finer-grained approach to street classification than the conventional Arterial-Collector-Local framework and its variants.

The variables used in the Context Zone classification system natural zone;

- rural zone;
- suburban zone;
- general urban zone;
- urban center zone; and
- urban core zone (ITE, 2006, p. 45).

For street planning and design purposes, the six context zones are matched by eight thoroughfare types, as displayed in the following list:

- high speed boulevard;
- low speed boulevard;
- avenue;
- street;
- freeway/expressway/parkway;
- rural highway;
- rural road; and
- alley/rear lane (ITE, 2006, pp. 48-59).

Design parameters are listed for four of these: High Speed Boulevard, Low Speed Boulevard, Avenue, and Street (ITE, 2006, pp. 48-49). The mixed-use urban arterial street can be categorized in any one of three Context Zones (General Urban, Urban Center, and Urban Core) and any one of three Thoroughfare Types (Low Speed Boulevard, Avenue, or Street), depending on location. Main and high streets would find a best fit in the Street/Thoroughfare type and in either the Urban Center or Urban Core Context Zone.

A variety of approaches to context sensitive urban street classification have also been developed in US cities and counties, including Denver, Colorado, and Arlington County, Virginia (City and County of Denver, 2002, & Arlington County, 2011). The research undertaken for this dissertation contributes new knowledge to this area by examining the relationship between the link and the place or, put another way, between the design of arterial streets and their urban context.

Cluster analysis of 126 streets and “characters sections” (street segments sharing notable characteristics) in nine European nations by the ARTISTS researchers was used to identify five distinct street types, as follows:

- low-intensity street;
- narrow inactive old street;
- shopping street;
- metropolis arterial; and
- suburban residential arterial (Jensen, 2004, p. 5).

Nine variables were used to differentiate street types: average building height, average distance between building lines, inactive building line, average number of floors, number of historically important buildings per 100 meters, average ratio of space between frontages, average width of public space between buildings, ratio of street width to building height, and number of doorways per 100 meters (Jensen, p. 12). This dissertation evaluates variations on the themes of two of these street types: Metropolis Arterial and Shopping Street.

The Social and Economic Life of Streets

Question 3: how do arterial streets contribute to social and economic life?

The socio-economics of streets.

Much of the social and economic life in cities takes place on the streets, arterial or otherwise. For Appleyard, et al. (1981), “the social relations that take place on the street, its potential for neighborliness and street life, are values of urban life to be treasured ” (p. 9). For Kostas (1992), “there are intricate levels of social engagement encouraged and hosted by the street structure” (p. 189). Jane Jacobs (1961), ever quotable, summarized the social role of city street sidewalks in these remarkable terms: “Lowly, unpurposeful and random as they may appear, sidewalk

contacts are the small change from which a city's wealth of public life may grow" (p. 72).

She described four conditions necessary for streets to produce "exuberant diversity": a mixture of land uses to provide "the presence of people who go outdoors on different schedules ... for different purposes"; short blocks that yield "opportunities to turn corners"; a close-grained mingling of buildings varying in age and condition; and a sufficient concentration of people, including residents (J. Jacobs, 1961, pp. 150-151). There was a synergy between residents and workers that produced more than the sum of their parts (J. Jacobs, 1961, p. 153). Her prescriptions for creating and maintaining streets that feed the economic and social life of cities and maintain city livability are inductive and ad hoc, a product of inspired intuition rather than formal analysis.

There is also a "social logic" in city streets. As Stephen Marshall (2009) has written:

The way that cities are laid out with public streets and private plots and buildings allows that right mix of surveillance, anonymity, personal control of own space, and so on, that make this space suitable for people who do not know each other. Basically, it allows a city to exist as a container for strangers. (p. 110)

As such, Marshall (2009) contends, "the social space of streets is the single contiguous public space off of which private spaces are carved" (p. 110).

The social life of streets is not all about strangers passing and sometimes interacting with one another, however. A recent appraisal of sustainable suburban high streets in the UK noted that, at least according to the "popular image", such streets were "the communal hub; a place where near neighbors 'bump' into each other on their way to the post office, parents accompany children to the library and the elderly swap local gossip at the bus stop" (Griffiths, Vaughan, Haklay, & Jones, 2008, p. 1155).

The American urban planner William H. Whyte (1980) used time-lapse photography to study the social life and human behavior of "small urban spaces", particularly street plazas. He found the presence of a high proportion of people in groups, especially in "twos and threes" to be "an index of selectivity" or a measure of the attractiveness of a place for social interaction or merely people watching (Whyte, 1980, p. 17). To foster and attract people, these spaces needed to offer

ledges, walls, and more formal seating suitable for small clutches of people to linger while interacting with each other and/or to “look at the passing scene” (Whyte, 1980, p. 46). It was best of all if they could do so while enjoying “the pleasure of being comfortably under a tree” (Whyte, 1980, p. 31).

Danish urban designer Jan Gehl (2006) contends that, “when traffic is slow there is life in the streets for this reason alone” (p. 77). If movement speeds on a street are reduced from 60 to 6 kilometers per hour, for example, there will appear to be ten times the number of people on the street since “each person will be within visual range ten times longer”. Public spaces in cities, including streets, can invite social activity when “external conditions for stopping and moving about are good”. These conditions, according to Gehl, include protection from crime, vehicular traffic, and unpleasant weather (Gehl, 2006, pp. 171-173). Aesthetic considerations or “the design of the space”, as well as a “sense of place” inspired by architectural quality support and complement the external conditions related to comfort (Gehl, 2006, p. 181).

The economic life of urban commercial and mixed-use streets constitutes a kind of marketplace. Allan Jacobs (1993) described this aspect of street life as follows:

Some streets are for exchange of services and goods; places to do business. They are public showcases, meant to exhibit what a society has to offer, and to entice. The entrepreneur offers the goods, displays them, comes out onto the street as much as will be allowed, with wares to be seen. The looker sees, compares, fingers, discusses with a companion, and ultimately decides whether to enter the selling environment or not, whether to leave the anonymity and protection of the public realm and enter into private exchange (p. 4).

Jones et al. (2007b) noted that commerce on many such streets sprung up because they were “key points on the urban road network, where businesses have been able to access a larger customer base than can be provided by the local community” (p. 63).

The New York City livable streets advocacy group, Transportation Alternatives (2008), claims that “in commercial districts, pedestrian street amenities draw more foot traffic, new shoppers and higher retail sales” (p. 25). The literature on economic effects of investments in making streets more active, sustainable, and lively is not extensive, however, partly because of the lack of before-and-after

economic appraisal of investments in the public realm (Buchanan & Gay, 2009, p. 29). Nevertheless, a number of both informal reports and more rigorous studies suggest that investments in streetscape amenities, pedestrian comfort, and traffic calming do produce economic benefits (Buchanan & Gay, 2009; Commission for Architecture and the Built Environment, 2007; Hass-Klau, 1993; Local Government Commission Center for Livable Communities, n.d.). The main, high, and mixed-use arterial street is, then, both a community venue and a marketplace.

Arterial streets as community venues.

In their study of high streets in the UK, Jones et al. (2007b) assert that, “the extent to which traditional mixed-use streets can act as ‘social glue’ remains open to debate and is empirically unproven” (p. 10). Nevertheless, the same study concluded that such streets teemed with people engaging in many different activities, some social and some solitary: “browsers, socializers, observers, waiters, resters, queuers, workers, entertainers, customers, inhabitants” (Jones et al., 2007b, p. 50).

Gehl (2006) concludes that the duration of stay influences the level of social activity on streets and in other public spaces: “If people are tempted to remain in public spaces for a long time, a few people and a few events can grow to a considerable activity level” (p. 79). People participating in one event or situation have an opportunity to participate in another, so that “a self-reinforcing process can begin” (Gehl, 2006, p. 81). Lengthy stays lead to lively streets. Public spaces of poor quality have “only the bare minimum of activity”. In contrast, within good quality public spaces “a broad spectrum of human activities is possible” (Gehl, 2006, p. 11). His study of twelve residential street sections in Kitchener and Waterloo, Ontario documented that stationary activities accounted for nearly 90% of the outdoor time of residents, compared to only 10% contributed by “come and go” activities (Gehl, 2006, pp. 183-184). Social contacts take place along a continuum from high intensity between close friends to low intensity or passive “see and hear” contacts among strangers (Gehl, 2006, p. 15). The quality of “space between buildings” on streets and squares contributes to “living cities, ones in which people can interact with one another” (Gehl, 2006, p. 21).

An important premise of the ARTISTS research into arterial street sustainability in Europe was that social interaction on streets is, on balance, a social “good”. Marshall et al. (2004) argue this point as follows:

People seeing and hearing each other and meeting and engaging with each other in public space is taken to be ‘good’ as a whole, although not all individual encounters will be positive. Behind this lies the general urban design tenet that ‘public places’ are good places and that there is generally a positive surveillance value to the presence of people, which would mostly outweigh the threatening presence of gangs or criminals. Streets that support or promote social interaction are therefore considered to promote quality of life through a good social environment (p. 29).

The ARTISTS researchers concluded that, “the presence of people is ... an indicator of potential or actual social and economic activity” (Marshall et al., 2004, p. 71).

Pendola (2008) tested the effects of main streets on the sense of community in four San Francisco neighborhoods. His cross-sectional survey research study controlled for demographic variables, but not for residential self-selection (i.e. whether or not people who were more sociable tended to locate in the environs of a main street). In two neighborhoods, Bernal Heights and West Portal, both within the catchment area of a traditional mixed-use main street, survey respondents showed “a significantly higher sense of community” than respondents from two other neighborhoods, one high density (Nob Hill) and one a “more suburban style city neighborhood” (Sunset) that were not in the catchment area of such a street. The author counsels caution in interpretation of these results due to sampling limitations (Pendola, 2008, p. 562). Another limitation of this study is that the author did not explore which attributes of main streets were important in contributing to a heightened sense of community.

In his path-breaking study, Donald Appleyard (1981) employed survey research and mapping techniques (by researchers and respondents) to test the effect of traffic on residents living along three San Francisco streets: Franklin, Gough, and Octavia. His well-known finding was that “feeling of community” greatly diminished as traffic volume increased. Octavia Street, which was used by an average of 2,000 vehicles per day, was “a closely knit community whose residents made full use of their street”. Franklin Street, with an average daily vehicle traffic count of 15,750, had “no feeling of community at all”. Community feeling on Gough, a street with 8,700 cars on it each day, was in between these two extremes (Appleyard, et al, 1981, pp. 22-24). A shortcoming of this study is that Appleyard and his colleagues limited their investigation to a hypothesis of the effect of traffic volume on the

residents of the streets he studied, ignoring many other variables pertaining to the streets themselves and otherwise that may help explain differences in community feeling.

Bosselmann, MacDonald, and Kronmeyer (1999) examined the effects of traffic volume and street type on “social interaction, perceptions of home territory, and the comfort of people’s daily lives” (p. 168). Their study used a 1:2 matched pair design and focused on three streets of a “residential boulevard” design: Ocean Parkway and Eastern Parkway in Brooklyn and The Esplanade in Chico, California. Each of the three boulevards was compared to two otherwise similar non-boulevard residential streets. The boulevards of this research were of the multiway design with a central roadway for higher speed traffic separated by landscaped medians on either side from access roads for slower local traffic (Bosselmann et al., 1999, p. 168).

Like Appleyard’s path breaking work, this research explored through survey research and mapping the relationship between traffic on the street and resident social interaction, street activities, and perceptions of “home territory”. Unlike Appleyard and his colleagues, however, the researchers found no clear pattern in the relationship between traffic volume and social interaction or cohesion. Residents on the heavy traffic boulevards rated their living conditions better than residents on the matched conventional streets with medium traffic. Only residents on conventional streets with light traffic assessed life on their streets as more sociable than residents of high traffic boulevards. The researchers concluded that while the evidence was not conclusive, it did suggest that boulevards might be more conducive to social interaction than conventional streets with similar volumes of motor vehicle traffic (Bosselmann, et al., 1999, p. 174). Hence the lateral separation between homes and faster moving traffic, as well as the presence of landscaping and street trees, may mitigate the effects of traffic on street social life. Like the Appleyard study it is modeled after, however, the Bosselmann, et al. research ignores a plethora of influences pertaining to street environments that may affect the social life of streets. This dissertation seeks to address (at least partially) the lack of comprehensiveness in some often generative and widely quoted works.

Mehta (2006) conducted an extensive study of social behavior and interaction in relation to “microphysical characteristics and uses” on what were described both as major commercial streets and neighborhood commercial streets (Massachusetts Avenue, the Elm Street/Davis Square area, and Harvard Street/Coolidge Corner) in

neighborhoods located in two cities (Cambridge and Somerville) and one town (Brookline) in the Boston metropolitan area. Mehta points out that a street may be lively because of both dynamic and static activities. Street liveliness was defined as “the presence of stationary, sustained, and lingering activities and social activities”. These social activities, “measured by the number of people in groups and their duration of stay”, involve two or more people interacting with each other either actively or passively” (Mehta, 2006, pp. 30-31).

The study employed direct and walk-by observation, pedestrian counts, survey interviews, and behavioral mapping. The latter method involved “mapping how people used streets, what they did, where they walked, sat, stood, gathered, and socialized and what facilities they used for either functional or recreational activities” (Mehta, 2006, p. 54). Mehta constructed a “Liveliness Index” to measure and express differences among street segments in degree of social interaction. Index variables comprised the number of people engaged in some stationary activity, the number of people in groups of two or more engaged in some social activity, and their duration of stay (Mehta, 2006, p. 86).

Street characteristics that fostered social interaction and liveliness included places to sit near activity-supporting stores and businesses; stores that were “places to meet neighbors, friends, and sometimes even strangers”; stores selling “goods and services for daily use in a manner and ambiance that was unique”; and the presence of wide sidewalks. Physical details of the streetscape were also important: articulation of building façade at street-level with “nooks, corners, alcoves, small setbacks, steps, and ledges”; cover by trees, canopies, and overhangs; and stores and street fronts in which “goods, service and activities inside could be seen, heard, touched and/or smelled from outside” (Mehta, 2006, pp. 153-158).

More than two-fifths of the social interaction observed in the study was “associated with eating and/or drinking”. Street block segments with stores selling goods and services that customers could consume outside were livelier than blocks that did not have such stores (Mehta, 2006, pp. 94-95). The number of stores and businesses on a street block segment was associated with more activity and liveliness. While the Mehta study was noteworthy for focused, detailed attention to urban design and land use data, it neglected to investigate the influence of transport and traffic conditions as well as neighborhood socio-economic variables on street liveliness.

Lillebye (2007) studied the relationship between motor vehicle traffic volume and the street as a “social arena” along twenty-six streets, squares, and shopping arcades in the Norwegian cities of Oslo, Trondheim, Bergen, and Hamar. His dependent variables were “social street activity”, “social duration”, and “pedestrian intensity”. Social street activity was discretionary or optional. Four parameters were both pre-cursors and determinants of social street activity: a “social intent”, a “social arena” or physical setting for social activity, a “social factor” leading people to transform necessary activities into optional ones, and “social comfort” due to subjective and emotional attitudes (Lillebye, 2007, p. xiv). Lillebye’s social street activity, more formally termed “optional social street activity performed singly or with other people” (Lillebye, 2007, p. 25), was derived from the concept of optional activities so important to Jan Gehl (2006), who describes them as “those pursuits that are participated in if there is a wish to do so and if time and place make it possible” (p. 9). These discretionary pursuits are in contrast to necessary activities, which are “more or less compulsory”.

Lillebye constructed a composite “Social Performance Ratio”, the ratio between social street activity and pedestrian intensity, to measure the degree of social interaction on a street. His research methods included interviews, counts, and observations. In contrast to Appleyard’s findings for San Francisco streets, he found that the hypothesis that traffic volume had an effect on social street activity was “neither confirmed nor refuted” (Lillebye, 2007, p. 523). Like Appleyard, et al. and Bosselmann et al., however, Lillebye did not differentiate among streets by prevailing motor vehicle speeds. Lillebye did find that “an architecturally attractive social area” generates social street activity (Lillebye, 2007, pp. xix-xx). Architectural quality attracts both pedestrians and merchants who wish to cater to them. While traffic has an indeterminate effect on street life, the effect of architecture is determinate. Lillebye (2007) interprets this difference as follows:

Motorized traffic must be assessed as part of the built environment where it actually occurs, meaning that if the physical environment of a particular arena is designed to simultaneously cater for a high level of motorized traffic and a high level of pedestrians, human interaction and social street activity might occur if the setting is functionally, architecturally and culturally appealing (p. xix).

While Lillebye's approach is exemplary in its thoroughness as regards pedestrian activity in relation to motorized traffic, his work is nevertheless limited in several key areas. Like Mehta, he neglects socio-economic influences from the area surrounding each of his study streets, as well as the effects of public transport service levels on the social life of streets. In addition, his research – as with Mehta's – lacks the narrative texture provided by street user surveys and focus group sessions. As is described in the next chapter, these limitations are addressed in the design of the research in this dissertation.

Montgomery (1997) argues that street cafés and “café culture” represents “one of the few remaining opportunities for public sociability” in a technological age (p. 83). This is because cafés offer “great interaction with the street” and provide a locus “to see and be seen” and to meet people (Montgomery, 1997, pp. 99-100). These social purposes of street cafés, in Jan Gehl's terms, are both “pretexts” and “destinations” (Gehl, 2006, p. 117).

Porta and Renne (2005) proposed a set of “social urban sustainability” indicators for neighborhoods and streets, based on a review of the urban design and urban planning literatures. The street indicators comprise “individual components that as a whole either add to or subtract from street vitality” (Porta & Renne, 2005, p. 53). These indicators include the following:

- sky exposure (or the amount of sky exposure with trees and building considered opaque);
- façade continuity (or the continuousness of the building façade such that it follows the line of sight);
- “softness”, a compound indicator that measures both transparency (amount of door and window area fronting a street) and transition space, a measurement of visibly accessible transition space (front yards, stoops, verandas, porticos, balcony awnings, entry setbacks, etc.) between the public and private realms;
- “social width” (a measure of the restriction or severance effect of motor vehicle travel lanes, parking strips, median strips, and the like have on social interaction between the curbs on either side of a street);
- visual complexity, or the amount of variety (color, texture, façade type, street furniture, pavement) in a streetscape; number of buildings;

- sedibility, a measure of seating opportunities;
- “detractors” such as blank walls, “aggressive” automobile facilities (traffic signs or traffic lights, gas stations, parking lots); and
- “rejecting objects” (poor quality graffiti, large dumpsters or rubbish bins, low-quality light poles) that discouraged social life (Porta & Renne, 2005, pp. 53-58).

Porta and Renne (2005) applied their indicators to a set of streets in Fremantle and Joondalup, in the Perth, Western Australia metropolitan area using photographs along the centerline of each street at twenty-five meter intervals. They used Autocad software to measure areas calculated as polygons. The higher street indicator values in the traditional, late Victorian urban fabric of Fremantle were in sharp contrast with those in the new town of Joondalup (Porta & Renne, 2005, pp. 59-62). While creative in approach, this *ad hoc* study did not treat the observable, measurable influences of urban design attributes on street use. Further, it did not explore the perspectives of street users themselves on valued street characteristics.

Arterial streets as marketplaces.

Mixed-use high streets are, in effect, marketplaces. Jones et al. (2007b) described their economic role as follows:

Mixed-use streets offer a wide range of retail and service activities, both public and private, and attract a range of businesses, from multiple chains to small independent suppliers. Each street has its own unique character, however, reflecting both local geographical and historical factors ... and local market conditions (p. 30).

Their study documented shopping patterns on three such streets: Tooting in South London, Ball Hill in Coventry, and London Road in Sheffield. Customers from outside of the local residential population visited the streets less often than those coming from outside the local area, but spent more time and more money per trip (Jones et al., 2007b, pp. 65-66). Over the course of a year, however, local residents spent more per customer than did those living elsewhere, who typically arrive by car (Jones et al., 2007b, p. 68). Businesses surveyed on each of the three streets reported that about one-third of their customers came from a “regional catchment area” (Jones, et al., 2007b, p. 64) beyond the local residential environs. Although this study was important in documenting differences between residents and non-residents in

patterns of commercial patronage, its utility is limited by a narrow focus on shopping behavior and no exploration of the influence street attributes have on street use.

Hass-Klau (1993) reviewed studies of the effects of traffic calming and pedestrian streets on retailing in German cities. She concluded that larger scale pedestrian zones had a greater positive impact on business turnover than smaller ones and that the car-free schemes had a greater positive impact on sales than did traffic-calmed streets. She observed that, despite having “much smaller” economic benefits for retailers than pedestrian zone schemes, traffic-calmed streets still provided “worthwhile effects on safety and pleasantness of the pedestrian environment” (Hass-Klau, 1993, p. 30).

Yiu (2009) studied the effect of pedestrianization on rental values in Hong Kong through comparison of one retail street (Sai Yeung Choi Street South) that was car-free from 4 PM until midnight each day to a street with motor vehicle traffic (Fa Yeun Street) nearby that accommodated car traffic all day. Ratable value was employed as a proxy for market rental value (Yiu, 2009, p. 15). Ratable values on the pedestrian-only street were found to be about 17% higher, *ceteris paribus* (Yiu, 2009, p. 15).

Drennen (2003) surveyed merchants on the traffic-calmed portion of San Francisco’s Valencia Street regarding the effects of the changes in street design. Valencia Street was re-stripped in 1999 to reduce the number of through motor vehicle lanes from four to two, provide left turn lanes at intersections, and create bicycle lanes on each side (Sallaberry, 2000). Nearly two-thirds (65%) of the 26 merchants who responded to the question thought that the design changes had a positive “general impact on business and sales” (Drennen, 2003, p. 8). Her research was limited to merchant opinion, thus was not an empirical study of the effects of street attributes on street use.

Jones et al. (2007a) identified a variety of street planning and design qualities important to the “vitality and viability of shops and businesses”. A high degree of accessibility “at a city level, by all modes of transport” is essential for major retail streets. Integration into surrounding residential street networks is important for high streets in local centers. A variety of “retail, professional and public services” affords synergy in use of the street for multiple activities. Provision for both through movement and “interchange for people on foot, using bicycles, private vehicles or public transport” fosters accessibility and generates activity. Attractive street design

that appeals to those “strolling, window shopping and visiting market stalls or pavement cafes” promotes business vitality along with quality of life (Jones et al., 2007a, p. 31).

The fiscal effects of good street design were evaluated by means of multiple regression statistical techniques in a cross-sectional study of ten London high streets: Chiswick, North Finchley, Hampstead, Clapham, Streatham, Swiss Cottage, Kilburn, Tooting, West Ealing, and Walworth (Commission for Architecture and the Built Environment, 2007). The researchers regressed scores on the Pedestrian Environment Review System (PERS), a walking audit tool created by the Transportation Research Laboratory (Reid, 2003), against both residential property prices and retail space rental prices. Results for the ten London high streets indicated that an increase of one PERS point in street design quality was associated with a 5.2% rise in residential property values and a 4.9% increase in shop rents (Commission for Architecture and the Built Environment, 2007, p. 6). Both results suggest that the market judges better street design to be economically desirable. While this study was exemplary in charting fiscal and economic effects of street design characteristics, it did not measure any behavioral effects of street design or gauge the attitudes of street users in relation to street attributes.

Buchanan and Gay (2009) reported results of a stated preference survey taken in 2002 along the Strategic Walks Network, comprising six walking routes within Greater London covering some 600 kilometers of urban and rural walking routes. The willingness-to-pay of respondents for an improved public realm was from £4 to over £35 per year person, depending on route attribute (Buchanan & Gay, 2009, p. 31). Presumably, these findings would translate, *ceteris paribus*, into greater demand for patronizing commercial streets possessing desirable design qualities for walking. Whitehead, Simmonds, and Preston (2005), in their computer simulation modeling study of prospective economic impacts of urban design improvements on “a major zone-wide scheme of urban quality improvements” in Manchester City Centre, however, cautioned that “negative feedback effects” can occur “if the improvements in urban quality generate additional volumes of traffic carrying ... additional shoppers” (Whitehead et al., 2005, p. 10).

“Active” Streets, Healthy Communities

Question 4: what makes arterial streets “active”?

Question 5: how do active streets contribute to healthy communities?

Active living.

A comprehensive report by the Surgeon General of the United States (U.S. Department of Health and Human Services [HHS], et al., 1996) documented the need for Americans to become more physically active. A review of studies on the link between physical activity and health status presented in the report concluded that “regular physical activity and higher cardiorespiratory fitness decrease overall mortality rates in a dose-response fashion” (HHS et al., 1996, p. 88) and also that “physical activity appears to improve psychological well-being” (p. 142). Even modest amounts of physical activity, especially for sedentary people, can be beneficial. HHS, et al. (1996) concludes the following:

The findings reviewed ... form the basis for concluding that moderate amounts of activity can protect against several diseases. A greater degree of protection can be achieved by increasing the amount of activity, which can be accomplished by increasing intensity, frequency, or duration. Nonetheless, modest increases in physical activity are likely to be more achievable and sustainable for sedentary people than are more drastic changes, and it is sedentary people who are at greatest risk for poor health related to inactivity. Thus the public health emphasis should be on encouraging those who are inactive to become moderately active (p. 148).

As of the year 2005, fewer than one-half of Americans were physically active, defined as at least 150 minutes per week of moderate-intensity activities such as “brisk walking, bicycling, vacuuming, gardening or anything else that causes some increase in breathing or heart rate” or at least 75 minutes per week of more vigorous such as “running, aerobics, heavy yard work, or anything else that causes large increases in breathing or heart rate” (*HHS, Centers for Disease Control and Prevention, 2008, pp. 1297-1299*). The US Centers for Disease Control and the American College of Sports Medicine has recommended that “every US adult should accumulate 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week” (Pate et al., 1995, p. 402).

Researchers in both public health and urban planning have argued that “increasing walking and bicycling as two means of improving health and quality of

life represents a shared goal between the fields of public health and urban planning” (Hoehner et al., 2003. p. 15). Toward this end, much more research was needed to “define the domains and the variables within the community environment” which conduce to more walking and cycling (Hoehner et al., 2003, p. 17). A report issued by the National Center for Bicycling and Walking (Wilkinson, 2002) on ways to foster physical activity through community design prescribes more and better sidewalks, safe and convenient crossings, bicycle friendly streets and slower motor vehicle speeds as four of seven principles in street design and retrofit projects. Adopting these measures will “get more people walking and bicycling” (Wilkinson, 2002, p. 11).

Moscovich (2003) asserts that “active living communities result from the interaction of many environmental, cultural, political and sociological factors” and that “the design of a transportation system is but one of them” (p. 34). He cites one example of the relationship of transportation system design and active transportation in Toronto, Ontario, where a re-configuration of a four-lane street to two through lanes, left turn lanes at intersections, and bicycle lanes in each direction resulted in little change in motor vehicle traffic volumes, but bicycle volumes that “increased significantly” (Moscovich, 2003, p. 38).

Anticipating Moscovich’s linkage of the transportation system to active communities, Handy et al. (2002) concluded that “the available evidence lends itself to the argument that a combination of urban design, land use patterns, and transportation systems that promote walking and bicycling will help create an active, healthier, and more livable community” (p. 73). Gehl (2006) pointed out that the quality of “streets and city spaces” affected the number of people using them and the amount of time people spent in these public spaces. On poorer quality streets, for example, “people hurry home”. On higher quality streets necessary, optional and “resultant” or social activities all increased (Gehl, 2006, p. 11).

Aytur, Rodriguez, Evanson, Catellier, and Roseamond (2007) describe the comprehensive nature of “activity-friendly” community environments as follows: “Activity-friendly environments depend upon appropriate integration of land use and transportation infrastructure, a mix of residential and commercial land use, and connected systems of sidewalks, bikeways, greenways, and transit” (p. 397).

Sugiyama (2008) lists “availability of various destinations nearby” and “quality of routes to such destinations” as important environmental characteristics

that facilitate active transport (p. 94). He notes that “physical activity does not have to be structured, planned exercise; it can be incidental activity such as brisk walking for transport or for recreation” (Sugiyama, 2008, p. 94).

Lee and Moudon (2004) reviewed the public health literature on environmental characteristics that foster or impede physical activity. They found three components of the environment most important for walking and bicycling: origins and destinations, the catchment area around origins and destinations, and the route to and from origins and destinations (Lee & Moudon, 2004, p. 150). In combination, these characteristics affect both the decision to walk or bicycle and how long one is willing to do either.

Frank and Engelke (2000) surveyed the literature to date on the relationship between physical activity and built form. While noting that “assigning causality remains elusive” since most of the studies in the literature were cross-sectional rather than dose-response or quasi-experimental, they assessed consensus variables relating built form to non-motorized travel. Among these variables were greater levels of (street) connectivity, bicycle and pedestrian friendly street design, and traffic calming measures. The authors add the significant caveat, however, that “few studies have attempted to rigorously determine the effect of street design” (Frank & Engelke, 2000, p. 118).

In a subsequent article, Frank and Engleke (2001) argue that various micro scale urban design variables influence physical activity in communities. These include “ample” sidewalks, crosswalks, as well as the placement and design of buildings and parking lots (Frank & Engelke, 2001, p. 210). They call for more research “to effectively measure the variation in level of physical activity across distinct land use patterns, including the impact of micro-scale urban form features that have been, to a large extent, neglected in the transportation planning literature” (Frank & Engelke, 2001, p. 215).

Sallis, Frank, Saelens, and Kraft (2004), in an extensive review of studies in the transport planning, urban planning, and public health literatures found that “land use, the transportation infrastructure, physical activity, and public health are ... closely interrelated” (p. 260) and “the design of communities and transportation systems was consistently related to active transportation” (p. 261). A variety of terms have been used to represent physical activity for transportation purposes including: walking and cycling for transportation, non-motorized transport, human powered

transport, and active transport (Sallis et al., 2004, p. 252). Whichever term was used, it was apparent that contemporary US communities had “engineered physical activity for non-exercise purposes out of many Americans’ lives” (Sallis et al., 2004, p. 255).

Ewing (2005) in a review of some fifty studies undertaken in the 1990s evaluating the link between the travel behavior of individuals and characteristics of the built environment at the neighborhood level, found the effect of street network design to be ambiguous. Grid street networks mean more direct routes for walking and cycling, but also disperse auto traffic more widely within neighborhoods; thus “it is difficult to say which modes gain relative advantage as networks become more grid-like” (Ewing, 2005, p. 72).

Handy (2005) summarized the literature on both travel behavior and physical activity to date, observing that each “provide relatively convincing evidence of an association between the built environment and physical activity” (p. 30). More detailed measures of the built environment, however, showed mixed results that “suggest our understanding of what exactly it is about certain places that leads to higher levels of physical activity is limited”. She concludes with the observation that “accessibility, measured in various ways, emerges most clearly from both literatures as an important condition for physical activity” (Handy, 2005, p. 30). In summary, “researchers must rely on theory, empirical evidence, and intuition in choosing which relationships to target for study” (Handy, 2005, p. 6). Handy cautions about the influence of “residential self-selection”, however, on reported or observed levels of walking and bicycling and that “correlation does not establish causation” (Handy, 2005, pp. 30, 34). Research for this dissertation revisits the relationship between detailed measures of the built environment and both walking and cycling.

A variety of studies have delved into the connection between the community built environment and active transportation. As summarized in Table 1, land use mix, residential density, presence of sidewalks and bicycle facilities, and the propensity to cycle to work or commute by public transport were all found in some of this research to be associated with more active, fitter communities. The scale of the analysis seems to matter, however. Research by Ewing (2005), for example, found a weak, yet counter-intuitive negative relationship between an index of land use sprawl and body mass index (BMI) in a comparison at the US county level. More focused study is needed at the street-level to investigate finer-grained influences on travel behavior, particularly walking and cycling.

Table 2-1

Associations with More Active, More Fit Communities

Author(s)	Location	Relationship
De Bourdeaudhuij, Sallis, and Saelens (2003)	Ghent, Belgium	Physical activity and sidewalks (men) + land use mix + ease of walk to work (women) +
Boarnet, Day, Anderson, McMillan, and Alfonzo (2005)	California	Children walking to school and sidewalks + Replacing stop signs with traffic signals +
Frank, Schmid, Sallis, Chapman, and Saelens (2005)	Atlanta	Moderate physical activity and land use mix + residential density + intersection density +
Frank et al. (2006)	King County (Seattle)	Bicycling and walking and land use mix + street connectivity + residential density + retail intensity +
Rodriguez, Khattak, and Evenson (2006)	Chapel Hill and Carrboro, NC	Neighborhood physical activity and small lot sizes + office, commercial uses nearby + pedestrian and bicycle facilities + housing type variety + reduced setbacks from street +
Lindström (2008)	Skåne, Sweden	Obesity or overweight and walking to work - public transport commuting (men) -
Wen and Rissel (2008)	New South Wales	Obesity or overweight and cycling to work (men) -

Walking and cycling for transport and recreation.

Research on environmental correlates of walking is summarized in Table 2. Presence of sidewalks and proximity of shops and stores and/or public transport stops are some of the key built environment variables positively associated with pedestrian travel. These cross-sectional studies tend to be limited in scope and lack the comprehensiveness required in research on the influence that built environment has on pedestrian use of streets. Nevertheless, a hopeful note is struck in this literature for those interested in evidence that improvements to the built environment can facilitate more active communities and streets. Sallis et al. (2009) found “evidence of a linear gradient in the relationship, such that the more supportive the reported built environment ... the more likely the person was to be sufficiently physically active” (p. 487).

At the same time, some evidence of residential self-selection, the propensity of people who are or wish to become more active to move to a built environment affording the opportunity to do so, rather than the built environment itself inducing existing residents to be more active, has also been detected (Cao, Handy, & Mokhtarian, 2006). Since good walking and cycling environments support active and sustainable streets, understanding what creates these conditions is an important emphasis in this dissertation research. The conditions for and influences on the amount of walking and cycling on arterial streets are important foci of this dissertation. Determinants of walking and bicycling are treated extensively in subsequent sections of this chapter.

Table 2-2

Associations with Walking

Author(s)	Location	Relationship
Troped, Saunders, Pate, Reininger, and Addy (2003)	Arlington, MA	Transportation physical activity and street lights + enjoyable scenery + sidewalks + traffic -
Cao, Handy, and Mokhtarian (2006)	Austin, TX	Walking and residential self-selection +
McCormack, Giles-Corti, and Bulsara (2008)	Western Australia	Walking for transport and nearby shops and stores + nearby bus stops + sidewalks + bicycle facilities + public transport stations + schools +
Sallis et al. (2009)	Belgium, Brazil, Canada, Columbia, Hong Kong, Japan and Lithuania	Physical activity and transit stop nearby + sidewalks + bicycle facilities +

Air emissions and active transport.

Research findings on air emissions and active transport show a mixed pattern, as displayed in Table 3. With the partial exception of high traffic city centers, more walkable areas tend to have lower concentrations of air pollution. While drivers take in more pollutants than pedestrians, the picture for bicyclists is less clear, mainly due to their higher rate of respiration. Nevertheless, there is little question that as zero emission modes of travel, a predominance of walking and cycling in an area results in lower air emissions. While motor vehicle traffic is a good proxy for air pollution at the street level, the distance from sidewalks and footpaths to vehicle travel ways is a good indicator of how much pedestrians are buffered from vehicular air emissions. Research data for this dissertation includes comparative metrics on average daily vehicle traffic, pedestrian and bicycle use of street right-of-way, amount of lateral

buffer between pedestrians and motor vehicle travel lanes, and the amount of right-of-way allocated to vehicles compared to pedestrians.

Table 2-3

Air Emissions and Active Transport

Author(s)	Location	Findings
van Wijnen, Verhoeff, Jans, and Buggen (1995)	Amsterdam	Drivers were exposed to more CO, benzene, toluene, and xylenes than were cyclists. Cyclists' uptake of NO ₂ was higher than for drivers.
Rank, Folke, and Jespersen (2001)	Copenhagen	Drivers were exposed to more CO, benzene, toluene, xylenes, and particulates than were cyclists. Bus commuters had the highest exposure to NO ₂ . Rail commuters had the lowest exposure to benzene toluene, xylenes, and NO ₂ .
Briggs, de Hough, Morris, and Gulliver (2008)	London	Pedestrians were more exposed to more particulate matter than were drivers.
Frank et al. (2006)	King County (Seattle)	Walkability Index and nitrous oxides (NO _x) + compounds (VOC) -
Marshall, Brauer, and Frank (2009)	Vancouver	Walkability Index and city center nitric oxide (NO) + city center ozone (O ₃) - in-city, but outside city center NO and O ₃ -

Sustainable Arterial Streets, Sustainable Cities

Question 6: what makes arterial streets “sustainable” and how do sustainable arterial streets contribute to sustainable cities?

Sustainable streets.

In a review of transportation and climate change issues, Chapman (2007) asserts that walking and cycling is “the ultimate ‘zero carbon’ and environmentally-friendly solution for personal transport” (p. 364). As such, these two modes needed to be included in sustainable streets. Including them, in turn, required “cycle lanes and pedestrian areas linked with improved road crossings and safer junctions” (Chapman, 2007, p. 363). Sustainable streets, in the view of Greenberg (2008) “increase the use of least-polluting ways to connect people and goods to their destinations, through greater use of non-polluting modes and reductions in vehicle miles of travel” (p. 29).

Bevan et al. (2007) describe the attributes of sustainable urban streets as including reduced energy consumption through energy-efficient movement of people and goods; lowered consumption of material resources by requiring less infrastructure and using recycled materials; smaller impacts to environmental resources, including air and water quality; supporting healthy communities by enhancing “livability, public health, safety and security”; and acting to support sustainability during implementation by minimizing construction-related social and environmental impacts (p. 7).

The European ARTISTS research assigned the sustainable arterial street with the following tasks:

- offer access to a range of users;
- be a destination for social and economic activity;
- serve as a conduit for “accessibility elsewhere”;
- promote “greener modes”; and
- minimize environmental impact (including accident risk and loss of amenity (Svensson, 2004, p. 10).

Fulfilling these tasks could be done best through street design and management based on “a people-oriented approach in which social, economic, and environmental considerations ultimately serve to promote people’s quality of life” (Svensson, 2004a, p. 7). For ARTISTS researchers, “arterial streets contributed to the social,

economic and environmental dimensions of the sustainability of the urban area as a whole” (Svensson, 2005b, p. 18). In this view, the sustainable arterial street both contributes to and is a link/place spatial subset of the sustainable city. As such, these streets nest like linear versions of Russian (“*Matryoshka*”) dolls (*Wikipedia: The Free Encyclopedia*, n.d.) into the larger urban context.

Kenworthy and Newman (1999) proposed the following set of goals and indicators for transport in a sustainable city that expand to an entire city or metropolitan area many of the attributes of sustainable arterial streets discussed above:

- reduce car use (VKT or VMT) per capita;
- increase transit, walk/bike, and carpooling and decrease solo car use;
- reduce average commute time to and from work;
- increase average speed of transit relative to cars;
- increase service kilometers/miles of transit relative to road provisions;
- increase cost recovery on transit from fare boxes; and
- decrease parking spaces per 1,000 workers in central business district (p. 19).

In the context of research on sustainable streets, determining how well goals and indicators like these are being met requires study of the accommodation for and use of these low or no polluting modes of travel. This in turn requires a detailed, holistic research approach to sustainable, active streets of the kind that has been lacking in the scholarly literature to date. The research undertaken in this dissertation seeks to help fill this important gap.

Energy, air and water pollution, carbon emissions effects.

A conclusion reached at the OECD Vancouver Conference, “Towards Sustainable Transportation”, was that “the major global impact of transportation results from release of carbon dioxide into the atmosphere, an almost inevitable consequence of the combustion of fossil fuels”. Further, that there was “the close link between energy use and CO₂ emissions” (OECD, 1996, p. 20). Local and regional air quality degradation due to transportation resulted from emissions of hydrocarbons, nitrogen oxides, and carbon monoxide (OECD, 1996, p. 23). Transportation activity also polluted surface and underground water resources due to “oil and hazardous

chemicals ejected from road vehicles during normal operation”, as well as “improper disposal of lubricating oil” (OECD, 1996, p. 27).

Todd Litman (2011) has proposed several transportation environmental impact assessment categories for sustainability. The six categories are shown below:

- air pollution;
- climate change;
- noise and water pollution;
- habitat loss;
- hydrologic impacts; and
- depletion of natural resources (Litman, 2011, p. 9).

Jones et al. (2007a) offered a more focused set of environmental considerations for assessment of the sustainability of arterial streets, as follows:

- environmental quality inside vehicles ([link](#));
- contributing to global warming ([link](#));
- environmental quality ([link](#));
- air quality on the footway ([place](#));
- noise level ([place](#));
- vegetation ([place](#)); and
- street infrastructure ([place](#)) (p. 162).

Studies on the energy and carbon emissions effects of modal choice show environmental benefits of non-motorized modes of travel and public transport. Two such studies that quantified these effects are summarized in Table 4. The Chester and Horvath (2008) research is noteworthy in that their data included sedans, sports utility vehicles (SUV), and pickup trucks, as well as the two rail systems (San Francisco Muni as a proxy for the light rail mode and Caltrain representing the commuter rail mode) that operate on travel corridors studied in research for this dissertation. Streets that accommodate and support light rail or urban bus services with high passenger loads, including as feeder services to commuter rail stations nearby, are more sustainable in energy and environmental terms. Similarly, streets that accommodate and support zero emission non-motorized modes of travel, including walking and bicycling, would likewise be more sustainable. An essential part of research into sustainable streets is the study of how to provide for these more benign travel modes.

Table 2-4

Energy and Carbon Emission Effects

Author(s)	Location	Findings
Higgins, P. and Higgins, M. (2005)	US	Substituting walking and cycling for a short auto trip would reduce national energy consumption by 2.56% and CO ₂ emissions by 0.24%.
Chester and Horvath (2008)	US cities	<p>Lowest to highest energy consumption by mode (per passenger kilometer): light rail, urban peak period bus, commuter rail, sports utility vehicle (SUV), and urban off-peak bus.</p> <p>Lowest to highest greenhouse gas emissions by mode (per passenger kilometer): light rail, urban peak period bus, commuter rail, automobile, and sports utility vehicle (SUV).</p> <p>Urban bus energy consumption and greenhouse gas emissions are highly sensitive to bus occupancy.</p>

There is also increased interest and experience in “green streets” as another manifestation of sustainable streets (Bevan et al., 2007; Greenberg, 2008; Nevue Ngan Associates & Sherwood Design Engineers, 2009). A green street has been broadly defined as “a street right-of-way that, through a variety of design and operational treatments, gives priority to pedestrian circulation and open space over other transportation uses” (City of Seattle, n.d., Background section, para.1). These are designed to better manage storm water runoff. They do this by preventing or reducing the flow or infiltration of pollutants like oil, grease, antifreeze, and heavy metals leaking from motor vehicle engines, brake pads, and tires, as well as pesticides and herbicides being washed onto pavements and then into bays, lakes, rivers, streams, and subsurface water resources (Nevue Ngan Associates & Sherwood Design Engineers, 2009, p. 15). Use of trees, grass swales and other natural landscaping, as well as light-colored pervious paving materials, in green street design also reduces the heat island effect (EPA, n.d.) that is produced by the

expanse of impervious pavement surfaces within street rights-of-way (Nevue Ngan Associates & Sherwood Design Engineers, 2009, p. 17).

Implementation of this street design has been limited to date, particularly for arterial streets. Sustainability trade-offs are an inherent part of green streets consideration, however, since provision of paved surfaces is necessary to sustain use of arterial streets by pedestrians, cyclists, and public transport. Nevertheless, the proportion of street right-of-way dedicated to pervious surfaces, as measured for the six arterial streets studied in this dissertation, is an indicator of street sustainability.

Socio-economic effects.

What makes for a “sustainable transport system”? OECD (2002) promulgated these requirements:

A sustainable transport system should provide access to people, places, goods, and services in an environmentally responsible, socially acceptable, and economically viable manner. Mobility for communication and for enabling social contacts, as well as movement of people and goods, is to be considered as a means rather than as an end in itself (p. 42).

Litman and Burwell (2006) categorized the socio impacts of transportation in terms displayed in following list:

- inequity of impacts;
- impacts on the mobility disadvantaged;
- human health impacts;
- community interaction; and
- aesthetics (Litman and Burwall, 2006, p. 335).

They also identified these categories of economic impacts:

- traffic congestion;
- mobility barriers;
- accident damages;
- transportation facility costs;
- consumer costs; and
- depletion of natural resources (Litman and Burwall, 2006, p. 335).

They also note that community livability includes “local environmental quality, the quality of community interaction and community cohesion (whether residents work together and support each other, sometimes referred to as ‘civil society’), and the

ability of a community to satisfy the basic needs of residents” (p. 341). As such, “community livability is sensitive to the quality of the public realm (public spaces where people can interact), of which the street system is a major component” (Litman & Burwell, 2006, p. 341). Measurement of the space afforded for pedestrian interaction and the amount of such interaction is thus essential for any research on sustainable streets.

Jones et al. (2007a) postulate sets of social and economic considerations for assessment of the sustainability of arterial streets, both in their link and place functions. Link social and economic considerations are as follows:

- safety of people in vehicles;
- safety of vulnerable road users;
- speed of moving traffic; and
- movement efficiency along link (p. 162).

Place social and economic considerations for places are similarly succinct:

- personal security;
- activities on street;
- people present;
- place viability; and
- delay moving around the place (p. 162).

The ARTISTS researchers quantified socio-economic sustainability of streets in a “movement efficiency indicator”, the ratio of people moving to vehicles moving on a street segment, as a proxy for “overall social and economic benefit relative to environmental disbenefit” (Marshall et al., 2004, p. 71). This indicator represented socio-economic sustainability. Marshall et al. (2004) described its rationale in these terms:

People’s use of streets as pedestrians is therefore taken to equate positively with socio-economic benefit and hence social and economic sustainability within that locale. The impact of people’s use of streets on environmental sustainability is effectively considered in terms of the negative impact of vehicles (p. 76).

Research for this dissertation emphasizes, as no scholarly work on sustainable streets has to date, the importance of how people use streets and their attitudes about street use. Both are keys to street social and economic sustainability.

Assessment of Sustainable Arterial Streets

Question 7: how can the potential for and performance of “sustainable”, “active” arterial streets be assessed?

Types of assessment.

The Mobility Efficiency Indicator proposed by the ARTISTS initiative, Mehta’s Liveliness Index, and Lillebye’s Social Performance Ratio are only a few of the many criteria or indicators regarding how sustainable and/or active are arterial and other streets. Gudmunsson (2004) defines an indicator as “a variable representing an operational attribute of a system” (p. 44). Sustainable transport indicators reflect performance of the transport system from “a comprehensive perspective including the well-being of both present and future generations, and taking environmental, social and economic issues into account” (Gudmunsson, 2004, p. 35).

Banister (2008) contrasts conventional transport planning and engineering and alternative or sustainable mobility views of the street. The former is premised on mobility and has a traffic focus. With this goal in mind, the street is conceived of as a road, travel is a derived demand, and travel time minimization becomes a primary objective in street planning, design and management. This in turn requires segregation of people and traffic. In contrast, the sustainable mobility view is premised on accessibility, is people focused, treats the street as space and travel as “a valued activity as well as a derived demand”, and thus holds reasonable travel time and travel time reliability as key objectives (Banister, 2008, p. 75).

Jones et al. (2007a) used a simple red (bad)/green (good) traffic signal format presentation of results of a Transport for London workshop. Attendees were professional stakeholders tasked to assess several sections of the A1 corridor in Islington, North London. Workshop participants ranked development priorities based on sixteen sustainability aspects (Jones et al., 2007a, p. 167). They produced a visually striking horizontal bar chart display of the results of this simple binary assessment. Evaluation of the freight element, for example, took into account the positive economic and negative environmental impacts of goods movement on corridor sustainability. Assessment elements are listed below:

- freight;
- bus user experience;
- traffic management;

- impact of buses on the environment;
- cyclist environment;
- pedestrian environment;
- traffic accessibility;
- traffic flow/congestion;
- transport interchange/public transport nodes;
- transport links/connectivity;
- environmental (generally);
- severance (generally);
- crime;
- leisure/shopping;
- character and vibrancy; and
- urban realm and open space (Jones et al., 2007, pp. 165-166).

While heuristics as used in the Jones et al. workshop is a guide to understanding, a multiple methods research approach using quantitative and qualitative data gathering techniques is required for comprehensive assessment of both streets and travel corridors. There is an important gap in the scholarly literature in this kind of comprehensive approach to assessment of sustainable, active arterial streets. Again, the design of the research in this dissertation is tasked with helping to fill this clear gap.

Sustainability indicators.

Litman (2011) proposes an extensive set of socio-economic and environmental indicators for sustainable transport. The socio-economic and environmental indicators most transferable to individual streets include those displayed in Tables 5 and 6. The Litman lists are ambitious. As was found in the ARTISTS research project and in this dissertation, availability of secondary source data for a comprehensive evaluation of sustainable, active streets is limited. Hence, extensive original quantitative and qualitative data collection is needed.

Table 2-5

Socio-economic Sustainability Indicators for Transport

Indicator	Measurement
User satisfaction ratings	User surveys
Commute time	Door-to-door travel time
Employment accessibility	Jobs within 30-minute travel distance
Transportation diversity	Variety and quality of transportation options
Land use mix	Schools, shops, etc. within walking distance
Mode split	Proportion of travel by non-automobile modes
Safety	Per capita crash disabilities and fatalities
Community livability	Meeting livability objectives
Non-drivers	Quality of transport and access
Fitness	Proportion of people walking and cycling

Note. Adapted from Todd Litman (2011). *Well Measured: Developing Indicators for Comprehensive and Sustainable Transport Planning*, pp.22-23. Retrieved from Victoria Transport Policy Institute (VTPI) website: <http://www.vtpi.org/wellmeas.pdf>

Table 2-6

Environmental Sustainability Indicators for Transport

Indicator	Measurement
Climate change emissions	Fossil fuel consumption and CO ₂ emissions
Air pollution	CO ₂ , NO _x , VOC, particulates, etc. emissions
Water pollution	Vehicle fuel losses
Noise pollution	Exposure to traffic noise
Land use impacts	Land devoted to transport
Resource efficiency	Non-renewable resource consumption

Note. Adapted from Todd Litman (2011). *Well Measured: Developing Indicators for Comprehensive and Sustainable Transport Planning*, p. 24. Retrieved from VTPI website: <http://www.vtpi.org/wellmeas.pdf>

Lauto and Toivanen (1999) used the indicators displayed in Table 7 to assess the socio-economic and environmental sustainability of transport and land use in Helsinki, Naples, and Bilbao. As with the Litman indicators, the adaptation and application of metrics like these to arterial streets requires focused original

quantitative and qualitative research scaled to the street and its environs. In some cases - e.g. vitality of the city centre - the scale of the street (compared to an entire district, city, or metropolitan area) is too small for meaningful analysis. In this dissertation research, traffic safety and land use mix are measured directly and noise and air emission effects are gauged by the proxy variable of traffic volume. Street user benefit in turn is measured through surveys and focus groups. Land coverage is approximated by the amount of street right-of-way in pervious surface. It should be noted that the term “segregation” refers to degree of land use mix (or separation) served by the urban transport system.

Table 2-7

Environmental and Socio-economic Sustainability Indicators for Urban Transport

Socio-economic	Environmental
Exposure to particulate matter, NO ₂ , Justice of exposure to particulate matter, NO ₂ , CO Justice of exposure to particulate matter, NO ₂ , CO Justice of exposure to noise Traffic deaths and injuries (Land use) segregation Total time spent in traffic Level of service of public transport and slow modes Vitality and accessibility of city centre Accessibility of services Transport user benefits	Transport emissions of greenhouse gases, acidifying gases, and organic compounds Consumption of mineral oil products Land coverage

Note. Adapted from “Spartacus System for Analyzing Urban Sustainability,” by Lautso, K. and Toivanen, 1999, *Transportation Research Record*, 1670, pp. 35-46. Copyright 1999 by the Transportation Research Board.

Level and quality of service.

Dowling and Reinke (2008) proposed multimodal level of service (LOS) metrics and methodologies for urban streets. The authors constructed models to predict level of service quantitative ratings converted to letter grades from A (highest) through F (lowest) that would be assigned to street sections by public transit riders, pedestrians, and bicyclists (Dowling & Reinke, 2008, pp. 94-95 and 83). Models estimation was through showing 145 people in four US urban areas (San Francisco, Chicago, New Haven, and College Station, Texas) video clips for each mode of travel, as well as on-board surveys of 2,678 public transport passengers in

Portland, Oregon, San Francisco, metropolitan Washington, DC, Oakland, California, and Broward County, Florida.

Unlike the other lists pertaining to sustainable transport in cities and on streets previously discussed, the metrics used in the Dowling methodology are well-rooted in the research literature and defined in a rigorous way. Since they are mode-specific, however, neither any individual proposed LOS metric and methodology nor all of them taken together comprehensively assess the arterial streets on which these modes operate. The research for this dissertation used the most salient of the variables (or approximations thereof) including: frequency of public transport service, number of benches available to public transport patrons, travel lane width, sidewalk width, number of motor vehicle travel lanes, motor vehicle traffic volume, motor vehicle speed, on-street parking provision, presence of trees, and proportion of heavy vehicles. Moreover, the dissertation research added value to the quantitative metrics through qualitative user assessment, as well as by differentiating between streets in larger city compared to smaller city contexts.

Street assessment metrics.

Jensen (2004) described a set of sustainable street Performance Assessment Indicators for the ARTISTS project. These included the following:

- total number of people killed and injured per 100 meters per year;
- total number of accidents per 100 meters per year;
- average speed of motorized vehicles;
- street users speed compatibility;
- average noise level in middle of footway;
- people movement/average annual daily vehicle traffic; and
- traffic congestion (Jensen 2004, p. 14).

Data for these indicators could all be collected in field studies or through secondary sources. These metrics have an ad hoc quality and also appear incomplete in that they do not take the perspective of street users into account. The key to use of the indicators is to integrate them in a holistic study so that they can contribute something more than the sum of their individual parts. Research for this dissertation used or adapted variables recommended as Performance Assessment Indicators by the ARTISTS project, including crashes, crash casualties, motor vehicle speeds, and the ratio of people to motor vehicles on the street.

The ARTIST project are defined a number of variables to describe arterial streets. These included the following:

- total width of general traffic lanes;
- total width of footways;
- distance between signalized junctions;
- number of pedestrians walking along the street;
- AADT;
- type of median; and
- lighting degree (Jensen, 2004, p. 13).

The research completed for this dissertation used some of these metrics or variations thereof, including space allocated to pedestrians and to motor vehicles, presence of traffic signals, and motor vehicle traffic volume as possible independent or explanatory variables.

Jones et al., (2007a) propose sets of possible link and place arterial street performance indicators (p. 162). The authors delineate three assessment components: objective performance data, professional perception and judgment, and stakeholder perception and judgment (Jones et al., 2007a, p. 147). All of the indicators arrayed in Tables 8, 9, and 10 belong to the first assessment category. While still having an ad hoc character, these performance indicators are comprehensive in nature based as they are in link/place and social/economic/environmental frameworks. Nevertheless, the indicators are silent on urban design values and highly abstract (“index/amount of greenery elements per 100 meters”) on accommodation of natural elements within street rights-of-way.

This dissertation research builds and improves upon many of these link/place variables or their analogues. Examples include vehicle, bicycle, and pedestrian collision rates; collision severity; 85th percentile motor vehicle speeds; public transport service; total people flow to motor vehicle traffic flow; frequency of street crossings, bicycle and pedestrian activity; amount of permeable surface and tree canopy; and motor vehicle occupancy.

Table 2-8

Link and Place Social Performance Indicators

Link or place	Social performance indicator
Link	Vehicle collision rates Severity of collisions Journey time reliability
Place	Street crime rate Street crime severity People engaged in necessary activities People engaged in optional activities Street use, day and night by season Age distribution of users Distribution of users (spatial) Accessibility by public transport

Note. Adapted from Jones, Boujenko, and Marshall, 2007, *Link & place: a guide to street planning and design*, p. 162.

Table 2-9

Link and Place Economic Performance Indicators

Link or place	Economic performance indicator
Link	Total flow of people/traffic flow Delays to vehicles, pedestrians, and between junctions Number of interruptions to pedestrian flow per kilometer
Place	Rental value Rental vacancy ratio Parking, loading availability Frequency, type of crossings Street level changes across the street

Note. Adapted from Jones, Boujenko, and Marshall, 2007, *Link & place: a guide to street planning and design*, p. 162.

Table 2-10

Link and Place Environmental Performance Indicators

Link or place	Environmental performance indicator
Link	Air quality inside vehicles Total vehicle emissions Number of green modes or lower emissions vehicles Average number of people per vehicle unit
Place	Pollutant concentrations Db (A) level at kerbside and inside property units Index/amount of greenery elements per 100 meters Sustainability of infrastructure

Note. Adapted from Jones, Boujenko, and Marshall, 2007, *Link & place: a guide to street planning and design*, p. 162.

In their study of three local high streets in the UK, Jones et al. (2007b) aimed to “investigate and record all the varied aspects of daily life on these case study streets - what people did there and what they felt about the streets” (p. xi). Their street performance assessment methods included counting pedestrians, conducting focus groups and workshops, administering household and business surveys, reviewing closed circuit television footage, and holding “community street audits” or walkthroughs with stakeholders along with a discussion at the end of the walk. This multi-measure approach yielded quantitative and qualitative assessment data. The list was lacking, however, in documentation of objective conditions on motor vehicle traffic and public transport operations, public transport and bicycle use, travel safety, land use along the street front, and other important variables associated with street performance. The research in this dissertation uses aspects of this and similar studies, but integrates these into a more comprehensive framework.

Visual assessment.

Ewing, King, Raudenbush, and Clemente (2005b) conducted a visual assessment study using color slides and video of 50 street segments viewed by 59 raters in New Jersey with the aim of “identifying the physical features that can make them into main streets” (p. 269). The authors used a cross-classified random effects model in their effort “to explain main street scores while controlling for viewer

effects, and to study the effects of viewer differences on main street scores while controlling for scene effects” (Ewing et al., 2005b, p 269). Their methodology included presentation of paired images, a panoramic image and a video clip of one street compared to an image and video clip of another street, for viewing by raters who used a seven-point Likert scale for rating. The intent of the authors was “to operationally define main streets” (Ewing et al., 2005b, p. 274). The outcome variable in this exercise was a main street score assigned by an individual viewer to an individual street. They note that the term main street was “a catchall for highways with mixed function” (Ewing et al., 2005b, p. 273). Significant scene variables explained a total of 90% of variation across scenes, as well as 39% of the overall variation that included both the variation across viewers and measurement errors (Ewing et al., 2005b, p. 275).

While this research is a brilliant approach to visual assessment of street character, it does not include such dynamic attributes as motor vehicle traffic, public transport services, bicycling, or pedestrian activities that do so much to define the nature of a street. The variables significant at $p=.05$ and the direction of visual association with main streets included the following:

- proportion of street frontage occupied by parked cars (+);
- proportion of street frontage occupied by tree canopy (+);
- curb extensions visible (+);
- proportion of buildings with commercial uses (+);
- underground utilities (+);
- quality of pavement maintenance (+);
- proportion of street frontage in “dead” uses (-); and
- number of travel lanes (-) (Ewing et al., 2005b, p. 276).

The research in this dissertation does include several variables similar to these identified by these researchers as being important to people’s perception of a “main street”, but it integrates them with other important issues in assessing sustainable arterial streets.

Moore et al. (2009) used an innovative technique of giving 30 residents of London, Sheffield, and Manchester disposable cameras to record positive and negative aspects of the environs within a five- to ten-minute walk of their homes (p. 66). The researchers coded the subjects of the photo images. Local facilities and

amenities (30.4%), interpreted as “having accessibility to a wide range of shops, cafes, and restaurants close to people’s home” was the most frequently photographed of the eleven subject categories (Moore et al., 2009, pp. 70 ,72), followed by the built environment (16.2%), views (9.6%), transport (8.4%), and open space and nature (8.3%). Interviews with the resident photographers after they took their photos indicated that accessibility was often seen as a positive aspect of life in the city (Moore et al., 2009, p. 70). This research was an innovative way to illuminate the importance of access to urban amenities to the participants. Nevertheless, it added little to understanding how specific street characteristics affected those residing in the street environs.

Designing Sustainable Arterial Streets

Question 8: what are ways in which to design “sustainable”, “active” arterial streets?

Street design.

Svensson (2004a) maintains that, “while it is relatively straightforward to design either a main road catering primarily for traffic movement or a street for urban activities, it is not so easy to combine the main road function and urban functions in the design of a sustainable arterial street” (p. 5). She also notes that there are “two separate compatibility issues that need to be resolved in the act of (street) design”. These are the “physical fit – or the ability to accommodate space for different uses” and “compatible use – the suitability for different uses to be located next to or mixed with each other” (Svensson, 2004a, p. 50). In the words of American urban designer Elizabeth Macdonald (2007), “ecologically and socially responsible street design calls for balancing how the public space of streets is used” (p. 27).

Hawkes and Sheridan (2009b) argue that “for the past century, street design has been geared towards the automobile”, and that “design regulations have prioritized uniformity and speed over character and livability, leaving pedestrians, bicyclists, and transit users competing for the residual space”. The result has been “streets with no sidewalks, sidewalks with no shade, pathways cluttered with telephone poles, utility boxes, and crisscrossed with access roads ...” (Hawkes & Sheridan, 2009c, Reclaiming the Street section, para.4).

Kubilins (1999) called upon traffic engineers to “refocus on modal choices: pedestrians, bicycles, automobiles, and transit” by stressing the importance of

relative speed in the design of “functional streets that contribute to our quality of life” (p. 1). She argued that “relative speed is the key to safe, multimodal streets” and that “land use and transportation must work in harmony” (Kubilins, 1999, p. 2). The importance of design speed for streets was apparent when comparing driver reaction and braking distance at 40 mph, about 300 feet, to only 100 feet at 20 mph (Kubilins, 1999, p. 3). Moreover, “the probability of a pedestrian being killed when a vehicle is travelling at 15 mph is 3.5%, compared to 37% at 31 mph, and 83% for a vehicle traveling at 44 mph” (Kubilins, 1999, p. 4).

The author of an authoritative report on context sensitive street design for major urban thoroughfares (Daisa, ITE, 2006) argues that “thoroughfare design should complement urban buildings, public spaces and landscape, as well as support the human and economic activities associated with surrounding land uses” in order to “serve the ... mobility, safety, access, and place-making functions of the public right-of-way” (p. 10). This approach heeds the advice given by d'Ieteren, et al. (2002) on “maintaining a holistic and integrated perspective” in designing streets toward sustainability (p. 13). The material to follow treats the ways in which a “holistic and integrated” perspective applies to the design of sustainable, active streets. As it is with design, maintaining this perspective is important to research on streets.

Complete streets.

Topp (1990) contended that “reduction of the ‘visual width’ of a street through “narrowing the carriageway, extending the sidewalks, installation of bicycle lanes, [and] planting of trees in the parking strips” not only reduces car speeds and separates bicycle from motor vehicle traffic, but also produced “more justice in the division of the street area” (p. 299). These ideas are the basis for the contemporary complete streets movement, an effort to create streets that, in the words of one American advocacy group, “are designed and operated to enable safe access for all users” so that “pedestrians, bicyclists, motorists and transit riders of all ages and abilities must be able to safely move along and across a complete street” (National Complete Streets Coalition, n.d., Complete Streets FAQ section, para 1).

LaPlante and McCann (2008) define a complete street as “a road that is designed to be safe for drivers; bicyclists; transit vehicles and users; and pedestrians of all ages and abilities” (p. 24). A complete street requires “more than simple allocation of street space” and creating one calls for “selecting a design speed that is appropriate to the actual street typology and location” (LaPlante & McCann, 2008, p.

26). This often is no less than “arterial traffic calming”, which is “one of the biggest challenges to engineers in that they tend to be the most hostile (streets) to bicyclists, pedestrians and transit riders” (LaPlante & McCann, 2008, p. 26). The effects of slower prevailing car speeds on motor vehicle travel time are minimal. Reducing the speed of a “five-mile (8 km) trip along an arterial corridor” at 45 mph (70 km/hr) to 30 mph (50 km/hr) only adds 2.5 minutes, while increasing both safety and city livability (LaPlante & McCann, 2008, p. 26).

McCann (2005) argued that the complete street should be the default mode for street designers, so that a justification must be provided otherwise. While design features for complete streets may vary depending on street context, “a complete street policy is aimed at producing roads that are safe and convenient for all users” (McCann, 2005, p. 18).

LaPlante (2007) asserts that a conversion of a four-lane street with two lanes in each direction to three lanes with one travel lane for each direction and a center-left turn lane at intersections “makes the prudent driver the ‘pace’ car for the roadway” and improves street safety (p. 5.). Another complete street measure is the raised center median, which “visually narrows the roadway and provides median refuge for mid-block (pedestrian) crossings” (LaPlante, 2007, p. 6). Moreover, adding curb bulb-outs at intersections and mid-block crossings reduces pedestrian crossing distance and improves pedestrian safety (LaPlante, 2007, p. 5). Illustrative design features of complete streets are as follows:

- reduced number of through travel lanes;
- bicycle lanes;
- raised medians;
- curb bulb-outs at pedestrian crossings;
- narrowed travel lanes;
- tightened intersection turning radii;
- parkway landscaping between curb and sidewalk;
- retained curbside parking;
- pedestrian “countdown” signals at crossings;
- accessible pedestrian crossing signals; and
- increased pedestrian crossing signal time (LaPlante, 2007, p. 27).

Policies fostering complete streets have been enacted in jurisdictions across the United States, as shown in the “Complete Streets Atlas” on the Complete Streets Coalition Web site (National Complete Streets Coalition, n.d.). King Street – The Embarcadero, the exemplary Big City arterial street in this dissertation research, is an example of a complete street design.

Road diets.

Burden and Lagerwey (1999) described road diets in whimsical fashion as “‘skinnying’ up patients (streets) into leaner, more productive members of society” (p. 3). They posit the four-lane street with annual average daily traffic of between 12,000 and 18,000 vehicles as an “ideal patient”, but also note that “especially sick four-lane patients” with daily traffic volumes of from 19,000 up to 25,000 may also qualify for a diet to reduce the number of through travel lanes from four to three or even two (Burden & Lagerwey, 1999, pp. 3, 6). The upper limit for four to three lane conversions, however, may be 30,000 vehicles per day on an arterial street, as was achieved by Kirkland, Washington on Lake Washington Boulevard (Burden & Lagerwey, 1999, p. 6). The authors proposed this list of best model street contexts that are especially favorable for “road diets”:

- moderate volumes (AADT = 8,000 to 15,000);
- transit corridors;
- popular or essential bicycle routes;
- scenic roads;
- economic enterprise zones;
- historic streets;
- main streets; and
- entertainment districts (Burden & Lagerwey, 1999, p. 7).

The re-design of Castro Street, the exemplary Small City arterial, was an early road diet project of the main street type.

Knapp and Rosales (2007) summarize “feasibility determination factors” and “implementation considerations” for road diets. Their extensive list includes substantial possible reductions in heavy vehicle speeds, elimination of “weaving and lane changes” on the road diet cross-section, and a preference for the three-lane compared to the four-lane cross-section on behalf of “pedestrians/bicyclists/adjacent landowners” (Knapp & Rosales, 2007, p. 4).

Research findings to date show crash reduction benefits of road diets, achieved without increased motor vehicle traffic congestion. Table 11 summarizes this research. Welch (1999) has asserted that reduced crash rates due to road diets are “primarily the result of the reduction of conflict points and improved sight distance for turning and crossing traffic” on street cross-sections with a travel lane in each direction and a center-left turn lane at intersections compared to street cross-sections with two travel lanes in each direction (p. 4).

Table 2-11

Road Diet Research Findings

Author(s)	Location and findings
Goodwin, Haas-Klau, and Cairns (1998)	60 locations in Western Europe, North America, Australia, and Japan One-quarter of vehicle traffic “disappears” from the street network after street capacity for motor vehicles is reduced. An extensive set of behavioral responses was apparent in traveler response to capacity reductions.
Huang, Stewart, and Zeeger (2002)	37 street segments in California and Washington state: 12 road diet streets and 25 conventional streets There was an average 6% reduction in crash rate with road diets, but no significant difference in crash severity or crash type, between road diet and conventional streets.
Knapp, Giese, and Lee (2003)	13 locations in Montana, Minnesota, Iowa, California, and Washington state There was evidence of crash reduction on all road diet streets. There was also some evidence of reduced motor vehicle speed and no evidence of increased motor vehicle speeds.
Pawlovich, Li, Carriquiry, and Welch (2006)	30 locations in Iowa: 15 road diet and 15 conventional street sections. There was an average reduction of 25.2% in crash frequency per mile and 18.8% in crash rate on road diet sections compared to conventional sections.
Rosales (2007)	5 locations in Washington state, Iowa, Georgia, Ontario, and New Zealand There was an overall reduction in crashes from 10% to 65% and no significant effect on traffic volumes or distribution of traffic.

Context sensitive streets.

The idea that streets have a context has become an increasingly important part of street design practice. Topp (1990) called for “compensatory measures”, including “improving the streetscape by planting of trees and reducing the (vehicle) speeds” as well as installing “traffic islands and center strips” on busy main thoroughfares (p. 299). Such measures made such streets “safer for the use of the street by pedestrians and bicycle riders”, reduced stress among street users, made the street appear “friendlier, more pleasant”, and improved the climate (Topp, 1990, pp. 298-299). Reducing vehicle speeds would also reduce street noise levels and the incidence of injuries and fatalities among pedestrians and cyclists. Lowering vehicle speeds from 65-70 kph to 50 kph, for example, would result in a noise reduction roughly equivalent to that caused by “halving the traffic volume”. Creating a safer, more comfortable environment on urban commercial streets for pedestrians was crucial, since “pedestrians produce urbanity” (Topp, p. 299).

Ewing (2002) observed that “context sensitivity” in street design implied “tailoring designs to adjacent land uses” and exercising “flexibility in choosing design values that “better fit the context” (p. 52). This flexibility was possible within the design parameters given in standard US street design guidance (AASHTO, 2004). Ewing listed the following elements as required for design of a traditional main street.

- design speeds as low as 30 mph/50 kph;
- travel lanes of 10-11 ft./3-3.4 m;
- minimum clear space from curb: 1.5 ft./5 m (3 ft./1 m near intersections);
- mid-block crosswalks;
- on-street parking;
- corner radii of 10-15 ft (3 to 4.5 m);
- raised pedestrian refuge islands);
- bulb-outs at pedestrian crossings;
- wide sidewalks: 12 ft (3.7 m) “encouraged”; 8 ft (2.4 m) “required”; and
- vertical curbs (Ewing, 2004, p. 54).

Streets and highways having “mixed functions, not just channels for vehicular movement, but places in their own right” required safe accommodation for

pedestrians and bicyclists, as well as “serious consideration of street aesthetics and a degree of traffic calming” (Ewing, 2002, p. 52).

Design insensitivity to street context may be driven by a focus on the needs of drivers.

Ewing (2002) asserts the following: What makes streets difficult to cross and unpleasant to walk along due to aggressive driving ... is the presence of multiple travel lanes, plus exclusive turn lanes at intersections. Multilaning of streets is not prompted by geometric standards, but instead by performance standards and driver convenience. (p. 58)

Street widening for vehicular traffic was often prompted by the need to meet motor vehicle level of service standards that put a premium on reducing vehicular travel delay, “regardless of the impacts on adjacent land uses” (Ewing, 2002, p. 59). In the words of a report on “civilizing” streets that serve as “downtown highways” (Congress for the New Urbanism; Local Government Commission; Surface Transportation Policy Project, 2002), in street design “throughput and efficiency have replaced the values of civic beauty and public access” (p. 19).

Ewing (2001a) also observed that, “instead of gracious boulevards, avenues and shopping streets, America’s urban areas are crisscrossed by arterials and collectors that move traffic but have no power to move men’s souls” (p. 4). There were exceptions to this rule, however. A number of street design projects across the nation respected the urban context in which they were located. Three such examples were US Route 6 in Brooklyn, Connecticut; East Main Street in Westminster, Maryland; and South Broadway (US 9) in Sarasota Springs, New York. Rather than create new vehicular travel lanes, West Palm Beach, Florida, reduced its vehicular level of service standards. The space that would have been reserved for vehicle movement instead accommodated widened sidewalks, on-street parking, and landscaped curb extensions and islands that encouraged street life (Ewing, 2001a, p. 10).

The definitive guide to context sensitive solutions (CSS) in the design of major urban thoroughfares (Daisa, 2006) lists these elements of effective CSS: a common understanding of project purpose, stakeholder involvement, an interdisciplinary design team, attention to community values, and objective evaluation of many alternatives (p. 7). Arterial and collector streets in urban areas are “thoroughfares ... multifunctional in nature, and are designed to integrate with

and serve the functions of the adjacent land uses” (Daisa, 2006, p. 13). Design criteria need to be applied flexibly in these environments, depending on key design controls, including location, functional class, design vehicle, and design speed (Daisa, 2006, p. 61). There were four roadside zones to consider in the design process: edge zone, furnishings zone, throughway zone, and frontage zone (Daisa, 2006, p. 96).

CSS for thoroughfares includes a number of design principles. Modal emphasis needs to be established early in the design process, rather than “addressed as an afterthought in preliminary engineering”. An understanding of “the relationship between the thoroughfare, adjoining property, and the character of the broader urban area” is necessary for the emergence of project concepts (Daisa, 2006, p. 22). Daisa cautions that, “the design of the individual thoroughfare is linked to the performance of the network” (p. 26). An alternative to “an emphasis on high levels of vehicle capacity on individual arterial facilities” is “building network capacity and redundancy through a dense, connected network” (Daisa, 2006, p. 27). The author provides extensive design guidance for urban thoroughfares, including along the roadside, in the travelled way, and at intersections (Daisa, 2006, pp. 95-180).

Context sensitive street design represents a paradigm shift in thinking for traffic engineers in designing multimodal streets rather than merely accommodating the growth in motor vehicle traffic. To reduce the overall tide of motor vehicle traffic to make more room for sustainable transport, however, requires sustained investment in on-street and off-street networks for public transport and non-motorized modes of travel. Castro Street in this thesis is the archetype of the Small City main street re-designed to better fit its land use context.

Street trees and landscaping.

Nature is an essential part of the street context, even in cities. Ulrich (1996) reviewed research findings on the human response to natural and visual landscapes, particularly those settings that contain trees and other vegetation (p. 29). Although Americans and Europeans had a strong preference for views of the natural landscape over urban views, appreciation for urban scenes tended to increase “when trees and other vegetation are present”. This may be linked to stress and anxiety reduction (Ulrich, 1996, p. 29). Scenes with trees typically elicited much more positive responses than those with “empty grass-covered expanses” (Ulrich, 1996, p. 40).

Sheets and Manzer (1991) conducted two studies on “cognitive and affective reaction to vegetation in urban settings” (p. 285). In one study, subjects viewed line drawings of streets with and without trees. In the other, subjects were shown slides of a suburban thoroughfare. In both cases, the addition of trees to the view increased the respondents “cognitions about the quality of life as well as the land-use of an area” (Sheets & Manzer, 1991, p. 295). The authors also found that the subjects “reported more positive feelings when viewing tree-lined city streets; they felt friendlier, more cooperative, less sad, and less depressed”. Further, “vegetated scenes were rated as better, safer, and cleaner places in which to live, and as easier places in which to make a living” (Sheets & Manzer, 1991, p. 302).

Foltête and Piombini (2007) investigated the role of landscape in fostering pedestrian activity. The authors argue that use of qualitative data on landscapes is important “in order to understand how individuals determine their routine trips in an urban environment and how they are affected by these trips” (Foltête & Piombini, 2007, p. 226). The “spatial preference” of walkers is influenced by “certain local characteristics such as presence of stores or other attractors, amenities that favor pedestrian movement, or even an attractive landscape” (Foltête & Piombini, 2007, p. 226). The researchers estimated a regression model with pedestrian counts as the dependent variable from a study frame of 1,148 street sections, or space between intersections, in Lille, France. They found that pedestrian count frequency was positively and significantly correlated with presence of trees, vegetation, squares, number of travel lanes, and “empty spaces”. Pedestrian frequency was negatively and significantly correlated with residential tall buildings (Foltête & Piombini, 2007, p. 230).

Maco and McPherson (2002) have noted that “street trees are an important part of the tree canopy over the city because of their prominence along heavily used transportation corridors” (p. 270). They ascertained six categories of tree canopy benefits:

- climate control;
- energy savings;
- air, soil, water quality improvement;
- storm water runoff mitigation;
- reduction of greenhouse gases; and

- increase real estate value (Maco & McPherson, 2002, p. 270)

Their research results and additional findings on tree canopy in urban settings are displayed in Table 12. Because of the demonstrated importance of tree canopy and other natural elements, these were incorporated into the research for this dissertation.

Table 2-12

Notable Tree Canopy Research Findings

Author(s)	Location and findings
Maco and McPherson (2002)	Davis, CA Tree canopy was estimated to be 24% over sidewalks and 34% over streets and sidewalks combined citywide.
Wolf (2003)	Los Angeles, Washington, DC, Chicago, Portland, OR, Pittsburgh, Austin, TX, and Seattle Survey respondents would visit business districts with trees more often, travel further, stay longer, and pay more for parking.
Wolf (2004)	Los Angeles, Washington DC, Chicago, Portland, OR, Pittsburgh, Austin, TX, and Seattle Street scenes with trees and buildings at urban densities were preferred by visual survey respondents. Both customers and merchants preferred street scenes with trees, but customers' preferences were higher.

Determinants of Travel

Question 9: what determines the demand for travel and choice of travel mode on arterial streets?

Reasons for travel.

While the street context influences the nature of travel, the reasons for travel reach beyond the street itself. A recent report issued by the National Research Council (2009) on the effect of the built environment, represented by residential and employment density and neighborhood or employment center design, illustrates the complexity of determining the demand for travel. Land use interacts with the transportation system, to affect destination accessibility (ease of travel between trip origins and desired destinations), thus travel demand (National Research Council, 2009, p. 51). While the built environment provides context for behavioral decisions about where to live, work, and shop, the choice of travel mode is also “strongly affected by age, income, and other socioeconomic variables” (National Research

Council, 2009, p. 33). Moreover, these influences are mediated by individual attitudes and preferences (National Research Council, 2009, p. 50).

Despite extensive research, the goal of “capturing the nature and magnitude of the link” between land use and travel has proven to be “elusive” (National Research Council, 2009, p. 89). Methodological difficulties in studying how the built environment influences travel include use of aggregate data that may “cloud the relationship between the built environment and travel behavior”, reliance on cross-sectional rather than longitudinal studies, subjects of studies self-selecting into environments that better suit their travel proclivities (thus creating an endogeneity bias), the difficulty in going beyond correlation to causality, measurement of variables, analysis measurement and scale issues, and the risk of generalizing the results of any given study (National Research Council, p. 2, pp. 54-64).

Results of recent studies of the effect of the built environment on vehicle miles of travel show that, after controlling for socio-economic influences and self-selection, there is “a statistically significant but often modest effect” (National Research Council, 2009, p. 75). The effectiveness of compact, mixed use development in reducing car travel can be increased through such policy measures as “a street network that provides good connectivity between locations and accommodates non-vehicular travel, well-located transit stops, and good neighborhood design” (National Research Council, 2009, p. 2).

Land use, urban form, and the built environment.

Newman and Kenworthy (2006) conclude that, “long term data from cities around the world appears to show that there is a fundamental threshold of urban intensity (residents and jobs) of around 35 per hectare where automobile dependence is significantly reduced” (p. 35). At a density of “at least 10,000 people and jobs in a 10-minute walk radius – or 100,000 in a 30-minute walk radius” it becomes possible to provide urban amenities and public transport, walking, and cycling become a viable alternative to the automobile (Newman & Kenworthy, 2006, p. 46).

Ewing and Cervero (2001) reviewed studies to date that sought “to explain four types of travel variables: trip frequencies (rates of trip making); trip lengths (either in distance or in time); mode choices or modal splits; and cumulative person miles travelled ... vehicle miles travelled (VMT), or vehicle hours travelled” (p. 87). Based on the research record, they concluded that household and socio-economic characteristics were more important than the built environment in determining trip

frequency; in fact, “overall trip frequencies vary little, if at all, between built environments” (Ewing & Cervero, 2001, p. 89). In general, however, “there has been far more research in land use patterns and their impact than on other features of the built environment”. The authors also concluded that “total household vehicular travel ... is primarily a function of regional accessibility” and that “any drop in automobile trips with greater accessibility, density, or mix is roughly matched by a rise in transit or walk-bike trips” (Ewing & Cervero, 2001, p. 92). Trip lengths, however, were typically shorter in more dense, accessible, and mixed land use environments. The effect of the built environment on vehicle miles of travel (VMT) and vehicle hours of travel (VHT) was considerably more significant and was “a product of differential trip lengths and mode splits that factor into calculations of VMT and VHT” (Ewing & Cervero, pp. 106-107).

Transit demand relies primarily on local densities and secondarily on the amount of land use mixing. Pedestrian demand, in contrast, depends equally on the degree of land use mixing and local land use densities so that, “a pedestrian-friendly environment is not exactly the same as a transit-friendly environment” (Ewing & Cervero, 2001, p. 82). Moreover, “much more empirical testing and replication of results” was needed to establish “what exactly constitutes transit friendliness or walking quality” and the relationship of both to travel choices (Ewing & Cervero, 2001, p. 106).

Ewing and Cervero (2001) found that destination employment densities are possibly of greater importance than population densities at the trip origins (p. 92). The authors conclude that “if any urban design features have any effect on travel independent of land use and transportation variables, it is likely to be a collective effect involving multiple design features” and possibly also the interactions between transportation and land use variables.

The same two authors have recently updated their review of travel and the built environment (Ewing & Cervero, 2010), noting an increased focus on transit use and walking as important outcome variables in more than 200 more recent studies. The newer studies included distance to transit service as a key built environment attribute and used increasingly sophisticated analytical methods (Ewing & Cervero, 2010, p. 266). Overall, they concluded that while the elasticity of travel with respect to the built environment was comparatively weak, the combined effect on travel

behavior of several built environment variables can be substantial (Ewing & Cervero, 2010, p. 265).

Ewing (2005a), in his literature review of some fifty studies undertaken in the 1990s evaluating the link between travel behavior of individuals and characteristics of the built environment, concluded that while “walking varies as much with the degree of land use mixing as with local densities”, the relationship between density and travel behavior is unresolved due to the probable co-variance of density with other factors such as good public transport service and a central location. However, public transport use varies primarily with density and secondarily with the land use mix (Ewing, 2005a, p. 72).

For Handy et al. (2002), the built environment comprises “urban design, land use, and the transportation system” (p. 65). The authors list several aspects of the built environment that are intertwined and generally correlated: land use density and intensity, land use mix, street connectivity, street scale, aesthetic qualities, and regional structure (Handy et al., 2002, p. 66). Since “density is often the easiest of these built environment aspects to measure, it is also the most frequently used. Land use measures are not standardized in the research record, however. While “high connectivity, human-scale streets, and desirable aesthetic qualities” are seen as making walking more viable and appealing, there had been to date little empirical work on the relationship between these characteristics and pedestrian behavior (Handy, et al, 2002, p. 66). There was a need for qualitative research methods in order “to identify the characteristics of the built environment that should be measured and to explore appropriate ways of measuring them”. As an example, “data on walking behavior must be spatially matched to detailed data on the built environment” (Handy et al., 2002, p. 72). Research for this dissertation answers this call for qualitative and quantitative analysis at a geographic scale where the built environment is most likely to influence pedestrian behavior.

Crane (2000) reviewed the extensive literature on the influence that urban form has on travel. While he found many research opportunities in the study of the effects that changes in land use and urban design had on travel behavior, there was “little verifiable evidence to support the contention that changes in urban form will affect travel”(p. 3). As a remedy, Crane prescribed “empirical work with some behavioral foundations” to examine how urban form and travel choices are linked (Crane, 2000, p. 4). According to Crane (2000), travel behavior was complex,

making it difficult to isolate and explain the role of individual features of the built environment. This research required “an analytical method that controls for as many differences between circumstances and behaviors as are necessary” (p. 11).

A confounding factor for those studies of the influence of urban form and land use on travel that focus on the neighborhood scale is the dominant role of regional circulation patterns (Crane, 2000, p. 12). Too much research in this area was *ad hoc* and lacked “a systematic choice theory to help identify how specific hypotheses with regard to urban form relate to the rationality of travel behavior”, thus making it difficult to compare results across studies (Crane, 2000, p. 14). While Crane’s observations have merit, the bewildering array of methodologies at varying spatial scales further complicate the research picture.

Cervero (2002) formulated a normative model for the study of mode choice, consisting of the characteristics of built environment, travel cost and the socio-economic attributes of travelers. The author describes the built environment famously as comprising “density, diversity, and design” (Cervero, 2002, p. 265). He asserts that studies focused on the effects of residential densities, extent of sidewalk provisions, and other built environment characteristics on modes of travel often neglect travel time and the price of auto use and, conversely, that mode choice models often neglected the influence of land development densities, land use mix, and urban design features in and around trip origins and destinations (Cervero, 2002, p. 266).

Maat, Wee, and Stead (2005) argue that the influence of compact urban design on motor vehicle travel reduction may not be as straightforward as it seems. Simple distance-oriented and trip-oriented approaches fail to examine the complex behavior entailed in travel demand and a broader framework is required (Maat et al., 2005, p. 33). Both the costs and benefits of travel needed to be considered. Activity-based theories of travel demand take into account that “most travel is derived from the need of individuals and households to participate in activities” (Maat et al., 2005, p. 37). Since these activities do not all occur in the same place, travel to and from them is required. Thus participation in activities yields benefits, but in order to access activities, travel costs, in terms of money, time, and energy, must be incurred. From the perspective of utility theory, households wish to maximize the utility of participating in activities. Since travel is ordinarily a cost or disutility, households seek to maximize the net utility of participating in activities less the financial and

time cost or disutility of travel. As a result, “individuals are not interested in travel distance, but rather in the cost of bridging that distance” (Maat, et al., 2005, p. 37).

People do not so much make individual decisions on whether to take a trip and by which mode; instead, they decide upon and schedule their activities. Since maximizing net utility from activities is the objective and each travel mode has a travel time associated with accessing activities, efforts to reduce the travel time differential between the car and alternatives to it will make those alternatives more attractive. The authors argue that “artificially extending distances for cars and slowing down car speeds in pedestrian-friendly and bicycle-friendly designs while extending car travel costs” make a “change to slow modes” more likely (Maat et al., 2005, pp. 41-42). This view understates the potential inherent in people-oriented links and places. Active, sustainable streets can increase the net benefit of travel as well as make travel for its own sake, as in recreational walking or cycling, more desirable.

The scholarly literature on the relationship between land use and the built environment to travel behavior is extensive and complex. There is considerable diversity in methods and at varying geographic scales in this literature. Despite this complexity, several themes are repeated in the scholarly record on land use and the built environment. Land use density and land use mix affect mode choice, as do access to public transport, proximity to destinations, the street pattern, and the quality of the pedestrian and cycling environments.

Despite the abundance of studies in this subject matter, there is a dearth of detailed research on the geographic scale of individual streets and their environs. Tables 13 and 14 summarize some notable contributions to this literature. The mix of methods and scales make characterization of overall findings difficult and potentially misleading. Nevertheless, there is strong evidence across methods and geographic scales that land use mix and accessibility to activity centers is associated with less auto use and more walking and cycling. Intuitively and as confirmed in the literature, access to transit influences transit use and presence of sidewalks and bicycle lanes contribute to more walking and cycling. While not universally confirmed in the research, many studies find that employment and population density are positively related to walking, cycling, and public transport use.

Table 2-13

Built Environment & Travel Research in Northern California

Author(s)	Location and findings
Kitamura, Mokhtarian, and Laidet (1997)	<p>5 neighborhoods in San Francisco, San Jose, Concord, and Pleasanton, CA</p> <p>The study controlled for socio-economic influences on travel. As access to rail transit increased, so did demand for both rail transit and non-motorized travel modes.</p> <p>Increased population density was associated with increased use of rail transit and non-motorized modes.</p> <p>The presence of sidewalks was positively related and distance to a bus stop or park was negatively related to use of non-motorized modes.</p>
Riley and Landis (2002)	<p>San Francisco Bay Area</p> <p>Built form variables improved a multinomial mode choice model.</p> <p>The measurable role of these physical factors was small, however.</p>
Handy, Cao, and Mohktarian (2005)	<p>8 Northern California neighborhoods</p> <p>The study controlled for residential self-selection.</p> <p>Changes in neighborhood characteristics explained more of the change in walking than the change in driving.</p> <p>Increased accessibility to commerce and employment had the greatest negative influence on driving.</p>
Handy, Cao, and Mohktarian (2007)	<p>8 Northern California neighborhoods</p> <p>The study controlled for socio-demographics and attitudes.</p> <p>The built environment attributes of attractiveness, safety, physical activity options, and opportunity to socialize increased residents' propensity to walk.</p>
Pinjari, Pendyala, Bhat, and Waddell (2007)	<p>Alameda County, CA</p> <p>The study controlled for residential self-selection.</p> <p>Higher population and employment densities, higher street block density, and the presence of bicycle facilities were all associated with higher walking and cycling mode shares.</p>

Table 2-14

Built Environment & Travel Research Elsewhere

Author(s)	Location and findings
Frank, and Pivo (1994)	Seattle Metropolitan Area Rising transit use occurred at densities of 75 Employees per acre and greater. There was increased choice of walking as a travel mode at population densities about 13 people per acre.
Cervero (1996)	US: National Housing Survey Grocery stores within 300 feet were associated with more walking and cycling for commute purposes. However, grocery stores between 300 feet and one mile away were associated with increased commuting by automobile.
Cervero (2002)	Montgomery County, Maryland Both increased land use density and increased land use mix significantly increased the odds of transit use. The influence of urban design was much weaker than was either land use density or land use mix. The Urban design variable was simplified to the ratio of sidewalk miles to street miles.
Greenwald (2003)	Portland, OR Metropolitan Area The choice of walking mode was positively associated with # of intersections, land use mix, retail employment, # of bus stops, distance to bus stop, and # of light rail stops. The choice of transit mode was positively associated with number of intersections, land use mix, retail employment, number of bus stops, distance to bus stop, number of light rail stops, and quality of the walking environment. These findings held even when controlling for residential self-selection.
Kirzek (2003)	Seattle Metropolitan Area The study tested for effect of Neighborhood Accessibility (NA), measured as a composite of residential density, block size, and land use mix, while controlling for residential. self-selection. As NA rose, VMT, person miles of travel in trip chains or tours, and # of trips per travel tour fell, while number of tours rose.

There is no clear consensus, however, on the influence of built environment variables on travel behavior or even on a definition of the built environment. The nature of the relationship seems to be contingent on the spatial scale at which research takes place. The characterization of one of the leading scholars in this literature, which conforms to the approach taken in this dissertation, is that “design generally reflects the quality of walking environments and the physical configuration of street networks” (Cervero, 2002, p. 270). Nevertheless, the scholarly literature lacks a detailed, comprehensive study at the level of the street and its environs of the relationship between the many aspects of the built environment and street use. This dissertation is intended to partially fill that vacuum in the scholarly record.

Determinants of Pedestrian and Bicycle Travel

Question 10: what determines the demand for pedestrian and bicycle travel on arterial streets?

Influences on walking and cycling.

The built environment is one of many influences on the decision to walk or bicycle. Saelens et al., (2003) reviewed research in the transportation, urban design, and planning literature on correlates of walking and cycling. They found that “communities with higher density, greater connectivity, and more land use mix” also had “higher rates of walking and cycling for utilitarian purposes” (Saelens et al., 2003, p. 80). There was a “similarity of findings across research designs and analytical methods” that “adds further to confidence in the results” (Saelens et al., 2003, p. 86).

Moudon and Lee (2003) prepared a synthesis of knowledge of walking, cycling, and the built environment, along with a behavioral model of walking or biking with three components: origin and destination, road characteristics, and characteristics of areas around origin and destination. They reviewed all instruments to audit physical environments for walking and cycling, whether for recreational or transportation purposes. They define an environmental audit instrument as “a tool used to inventory and assess physical environmental conditions associated with walking and bicycling” (Moudon and Lee, 2003, p. 21). Such audits use spatio-physical, spatio-behavioral, spatio-psychosocial, and policy-based variables. Walking and cycling conditions depend on three factors: interpersonal, environmental, and trip characteristic (purpose and length). All interact in complex

ways to influence the decision about whether to walk or bike (Moudon & Lee, 2003, p. 22).

The immediate physical environment is particularly important to those traveling on foot or by bicycle. It is important to assess this environment in detail since pedestrians and cyclists “move relatively slowly through the environment and are afforded an intimate experience of the environment around them that affects where and how long they choose to walk or bike (Moudon & Lee, 2003, p. 23). The researchers also assert that “work remains to assemble objective data of environments at a grain or resolution fine enough to correspond to those sensed by walkers and bicyclists” and that the absence of detailed and accurate information is the most important research need regarding environmental influences on walking and bicycling (Moudon & Lee, 2003, p. 36).

Pikora, Giles-Corti, Bull, Jamrozik, and Donovan (2003) consulted the literature then interviewed experts in urban planning, local government, transport planning, public health, as well as advocates for pedestrians, cyclists, and people with disabilities. Their purposes were to conduct a Delphi study of the possible influences on walking and cycling and to determine the perceived relative importance of these influences. The authors classified four key themes in research on walking and cycling environments: functional, safety, aesthetic, and destination. Panelist interviews elicited personal safety, attractiveness, and the presence of destinations that gave the trip a purpose as the most important determinants of walking. The most important factors for cycling were route continuity and speed and volume of traffic (Pikora et al., 2003, p. 1698).

Some of the most important research on factors that influence the decision to walk or bicycle is summarized in Table 15. Built environment influences on the propensity to use non-motorized modes of travel that have been identified in this research include route quality, land use characteristics at both trip ends, bicycle and pedestrian friendly design, and street connectivity. While there is evidence that the built environment is an important influence, personal and household attributes, as well as the trip characteristics, are even more significant considerations in this decision. Interestingly, there is evidence that route preference considerations hold constant across nations.

This dissertation investigates the influence of the built environment, land use, and route characteristics on street activity and sustainability. A key focus is how pedestrians and bicyclists contribute to sustainable and active streets.

Table 2-15

Notable Research on Factors Influencing the Decision to Bike or Walk

Author(s)	Location and findings
Westerdijk (1990)	<p>Britain, Sweden, and The Netherlands</p> <p>Pedestrian and cyclist route preference varied little across countries.</p> <p>The most important factors for pedestrians were distance and pleasantness of a route.</p> <p>The most important factors for cyclists were distance, pleasantness, and traffic safety of a route.</p> <p>There was evidence that these factors are traded off against each other in route choice decisions.</p>
Cervero and Duncan (2003)	<p>San Francisco Bay Area</p> <p>Propensity to walk and jobs within one mile radius (+)</p> <p>walk friendly design at trip origin (+)</p> <p>walk friendly design at destination (+)</p> <p>land use mix at origin (+)</p> <p>land use mix at destination (+)</p> <p>Significant variables associated with propensity to bike:</p> <p>jobs within five-mile radius (+)</p> <p>retail/service job density within one mile radius (+)</p> <p>bike friendly design at origin (+)</p> <p>bike friendly design at destination (+)</p> <p>land use mix at origin (+)</p> <p>land use mix at destination (+)</p> <p>Personal and household attributes and trip characteristics were more important than the built environment in the propensity to walk or bike.</p>
Dill (2004)	<p>Portland, OR Metropolitan Area</p> <p>There was a .902 correlation between street network link density and intersection density</p> <p>A high degree of street connectivity gives walkers and cyclists a wide range of route choice.</p>

Why walk?

Why do we walk? How long are we willing to walk and for what purposes?

Marchetti (1994) argues that from an anthropological perspective, humans are

territorial and seek the shelter of the cave. These two characteristics are balanced through the parameter of mean travel time per day. This balance is struck at one hour per day “mean exposure time” moving from one place to another (Marchetti, 1994, p. 75). The radius of travel is set by multiplying travel time by speed of travel. For the cities, towns, and villages before about the year 1800 that relied mainly on pedestrian travel, an hour round-trip at 2.5 kilometers per hour walking speed implied that the area of a settlement would have a radius of no more than 2.5 kilometers. There are no city walls of large ancient cities that exceed this limit (Marchetti, 1994, p. 77). While the city defined by the pedestrian has given way to the multimodal city whose radius is described by much faster modes of travel, walking remains ubiquitous in cities and the quality of the pedestrian environment is a key element of urban sustainability. Marchetti’s concept of mean exposure time has an intuitive appeal, is helpful as a metaphor, but eludes empirical confirmation.

Newman (2003) argues for the re-emphasis on the essential role of walking in cities because advances in information technology and the knowledge economy depend both on electronic and in-person communication (p. 100). As a result, he argues, “the coffee shops and mixed use, dense urban environments of city centres and inner areas where the car is not dominant” are an essential part of a rising “global economy city” (Newman, 2003, p. 100). Moreover, our evolution and history as a species show that “we need to walk and we want to be part of walkable environments”. In sum, “this is built into us and we need to build it into our cities” (Newman, 2003, p. 101). While Newman’s argument is a hopeful one from the perspective of sustainable transport, information age cities could just as well impel people to spend more time in isolation, communing with their social networks through electronic means rather than in person over espresso drinks at coffee bars.

Alfonzo (2005) posits a hierarchy of walking needs, including “feasibility, accessibility, safety, comfort, and pleasurability” (p. 830). Feasibility, or practicality, is affected by an individual’s physical condition and time constraints (Alfonzo, pp. 824-826). Accessibility comprises the variety and proximity of destinations as well as the connectivity between them (Alfonzo, 2005, pp. 826-827). Safety pertains to protection from threat of crime (Alfonzo, 2005, pp. 827-828). Comfort relates to “a person’s level of ease, convenience, and contentment” (Alfonzo, pp. 828-829). Pleasurability, in contrast, pertains to “the level of appeal that a setting provides with respect to a person’s walking experience” (p. 829). He cautions, however, that the

hierarchy of walking needs only applies to situations in which a choice to walk exists (Alfonzo, 2005, p. 831). This view is reasonable with the proviso that different individuals may make different trade-offs among components of a walking needs hierarchy. Accessibility may be most important to one person in choosing a walking route, for example, and aesthetic pleasure may trump access for another. Moreover, individuals may have different marginal rates of substitution along the walking needs hierarchy depending on trip purpose.

Shay, Spoon and Khattak (2003) surveyed the literature on walkable environments and walking behavior, described what constitutes a walkable environment, and summarized research on walking for both utilitarian and non-utilitarian purposes, as well as on pedestrian safety (p. 2). They assert that while “walkability is gaining prominence in the professional discourse of public health, planning, policy, and engineering”, to date there was “little agreement as to what truly defines a walkable environment” (Shay et al., 2003, p. 3). Nevertheless, they identify a short list of consensus variables that belong to a walkable environment: “mixed land uses, destinations within walking distance, presence of pedestrian supports such as sidewalks, and good connectivity of roads and pedestrian networks” (Shay et al., 2003, p. 13). The authors observe that there the research on walking was far from complete, partly due to “the complex interactions between human behavior and environments with a rich variety of combinations and formulations of design and function” (Shay et al., 2003, p. 16). That research in walkability is nascent is a striking statement in context of walking being the oldest mode of human transport.

Untermann and Lewicki, (1984), early proponents of creating more walkable cities and towns, observed that “travel on foot allows people to meet and greet each other, to look at and become part of the neighborhood”, thus offering “true accessibility to the life within our communities” (p. x). In their view, “the secret of pedestrian improvement is to reduce the walk length with short cuts, to intensify activity, and to improve intermediate distance substitutes – bus, bicycle and taxi” (Untermann and Lewicki, 1984, p. 25). For Untermann and Lewicki, there are three categories of pedestrian improvements: safety improvements to reduce conflicts with cars; functional upgrades to extend the pedestrian’s physical limitations; and “pleasurable changes”, which “are sensory and extend our psychological limits” (Untermann and Lewicki, 1984, p. 26). They list 10 important ways to better accommodate pedestrians:

- mixed land use;
- activity and people;
- window shopping opportunities;
- restaurants;
- unfolding views, diversity (of sights);
- nearby destinations;
- compact land uses;
- public transportation;
- shortcuts; and
- sidewalks (Untermann and Lewicki, 1984, p. 29).

Untermann and Lewicki contend that visual stimulation helps emphasize how much progress pedestrians make during their walk. Pedestrian furniture not only enhances the visual experience, but also reduces the apparent walk length (Untermann and Lewicki, 1984, p. 27).

Pedestrian perceptions are also influenced by the relative speed of walking.

Rapoport (1987) asserts the following:

At driving speeds, the time available to obtain information is ... greatly reduced. The need is thus for large-scale elements and infrequent broad and smooth rhythms. The pedestrian receives very different input – it is fine-grain, he can vary the rate, he can look around and stop to observe detail, he is aware of the environment all around him in all sense modalities. Motorists' perceptions are affected by the length of time each element is in view and also by the criticality of the task. The pedestrian has each element in view as long as he wishes and can satisfy his interest in it because of the low criticality of the task (p. 88).

Although this view has merit, it does understate the imperative in utilitarian walking, as well as in vigorous walking and jogging for exercise, of moving quickly from A to B.

Jaskiewicz (1999) proposed a variety of specific evaluation measures for assessment of the aesthetics, safety, and ease of use of the pedestrian environment. Enclosure better defines the street edge, puts “eyes on the street”, and conveys a feeling of narrowness to motorists, thus inducing slower speeds and safer driving (Jaskiewicz, 1999, p. 3). Complexity of path network gives pedestrians more route

choices and both building articulation and complexity of spaces adds interest to the walk (Jaskiewicz, 1999, pp. 4-5). Overhangs, awnings, and varied roof lines and shade trees add to the pedestrian sensory experience and well as provide protection against sun and rain. Buffers increase both actual and perceived safety by separating the pedestrian from moving traffic (Jaskiewicz, 1999, p. 6). Transparency provides a “smooth interface” between public and private realms (Jaskiewicz, 1999, p. 7). Physical components/condition elements, such as sidewalk design and condition, street design speed, pedestrian crossing treatments, etc. affect pedestrian safety and comfort (Jaskiewicz, 1999, pp. 7-8).

Southworth (2005) describes several criteria for the successful pedestrian network design for a walkable city: connectivity, linkage to other modes, fine-grained land use patterns, safety (traffic and crime), and path content (p. 246). The term path content comprises street design, visual interest, transparency, spatial definition, landscape, and overall explorability (Southworth, 2005, p. 247). In order to succeed, pedestrian environments must be “well supported by transit and situated within an accessible mix of land uses” (Southworth, 2005, p. 251). Southworth’s urban design perspective rightly emphasizes the finer grain attributes of the street and its environs in supporting pedestrian activity. Nevertheless, this perspective does not give enough weight to two crucial elements that foster foot traffic: sufficient moving and gathering space for people and buffers between pedestrians and motor vehicle traffic.

Ewing, Handy, Brownson, and Clemente (2009) attempted to quantify urban design perceptual qualities pertinent to walking on commercial streets. They sampled streetscapes with a visual assessment survey of detailed physical features representing the following urban design qualities found in the literature: imageability, visual enclosure, human scale, transparency, and complexity (Ewing et al., 2009, p. 65). The authors observed that the conceptual framework for their study “considers the role of perceptions as they intervene (or mediate) between the physical features of the environment and walking behavior” (Ewing et al., 2009, p. 67).

These scenes were shown to a panel of ten urban design and urban planning experts whose ratings of the urban design qualities in each were used as dependent variables to estimate statistical models. Various aspects of the physical condition of the street were used as independent variables (Ewing et al., 2009, p. 71).

Imageability was defined operationally as “the quality of a place that makes it distinct” (Ewing et al., 2009, p. 73). Enclosure was defined as “the degree to which streets ... are visually defined by buildings, walls, trees, and other vertical elements” (Ewing et al., 2009, p. 75). Human scale was “the match between the physical elements of the street and the size and proportion of humans”, as well as how these physical elements correspond to human walking speed (Ewing et al., 2009, p. 77). Transparency is defined as “the degree to which people can see or perceive what lies beyond the edge of the street” (Ewing et al, 2009, p. 78). Complexity is the quality of visual richness (Ewing et al., 2009, p. 81). The researchers found correlations of significant physical features to each design quality, as shown in Table 16. The framework of Ewing and his colleagues, which is readily transferable to the study of arterial streets, was one of the influences of the choice of variables to study in this dissertation research. These influences are described in the concluding section of this chapter.

Table 2-16

Physical Features of Urban Design Qualities

Quality	Most significant features
Imageability	Proportion, historic buildings (+) Major landscape features (+) Outdoor dining (+) Courtyards, plazas, parks (+)
Enclosure	Proportion sky across (-) Proportion sky ahead (-) Proportion street wall, same side (+) Proportion street wall, opposite side (+)
Human Scale	Proportion first floor with windows (+) Long sight lines (-) Urban designer used (+)
Transparency	Proportion first floor with windows (+) Proportion street wall, same side (+) Proportion active uses (+)
Complexity	Outdoor dining (+) Public art (+)

Note. Adapted from “Measuring the Unmeasurable: Urban Design Qualities Related to Walkability,” by R. Ewing, S. Handy, R. Brownson, and O. Clemente, 2009, *Journal of Urban Design*, 14, p. 72. Copyright 2009 by the Taylor & Francis Group.

Day, Boarnet, Alfonzo, and Forsyth (2006) developed the Irvine-Minnesota Inventory to Measure Built Environments to assess the land use, design, and traffic environments facing pedestrians. The researchers performed a literature search, convened focus groups, consulted an expert panel, and conducted field tests at 27 sites, mainly in Southern California (Day et al., 2006, p. 147). The Inventory comprises 162 items, grouped in four “domains”: accessibility, pleasurableability, perceived safety from traffic, and perceived safety from crime (Day et al., 2006, pp. 148-149). Table 17 displays the component variables in each of these domains.

Table 2-17

Walking Environment Assessment Domains

Domain	Variable
Accessibility	Land use mix Density Street pattern Slope Integration of uses
Pleasurability	Aesthetic appeal Attractive destinations
Perceived safety from traffic	Beliefs about opportunities for injury
Perceived safety from crime	Beliefs about opportunities for crime victimization

Note. Adapted from “The Irvine-Minnesota Inventory to Measure Built Environments: Development” by K. Day, M. Boarnet, M. Alfonzo, and A. Forsyth, 2006, *American Journal of Preventive Medicine*, 30, pp. 146-147. Copyright 2006 by the American College of Preventive Medicine & Association for Prevention Teaching and Research.

The structure beneath the urban design and other qualities that attract pedestrians is the street network itself. Hillier, Penn, Hanson, Grajewski, and Xu (1993) studied the configuration of the urban street network as a generator of patterns of movement, where retail and other land uses are then located “to take advantage of the opportunities offered by the passing trade” (p. 29). The form of the street grid gives a location advantage to certain spaces, which are then filled by retail and other land uses. The more integrated the street system, the greater the effect. From a space syntax perspective, “it is not the local properties of a space that are important in the main but its configurational relations to the larger system” (Hillier et al., 1993, p.

29). As such, “urban systems configuration is the primary generator of pedestrian movement patterns” (Hillier et al., 1993, p. 31). They assert that “natural movement in a grid is the proportion of urban pedestrian movement determined by the grid itself” (Hillier et al., 1993, p. 32). Shops and other pedestrian attractors serve to multiply the natural movement effects (Hillier et al., 1993, p. 48). The researchers studied the relationship between street grid integration and pedestrian volumes in ten subareas of Kings Cross in London and found strong correlations between volumes of moving and stationary adults and degree of integration of the street system (Hillier, et al, 1993, p. 46).

Despite its apparent empirical confirmation in the Kings Cross study, the space syntax explanation for pedestrian activity is far too abstract to apply at the level of an arterial street segment. The variations between streets in land use, streetscape and street front, right-of-way allocation, transport alternatives, access to gathering spaces, availability of vistas, provision for nature, and other influences on the choices to walk and to linger are too great to be accounted for within this framework. In this context, it is prudent to heed the warning of one researcher about “the reductionist tendency for viewing variables in isolation”, which does not capture the “synergistic qualities of pedestrian environments” (Lamont, 2001, p. 32). Nevertheless, the research in this dissertation incorporates particular variables which provide insight into their main argument about urban systems configuration.

There has been extensive research in recent years on the correlates of walking. Owen, Humpel, Leslie, Bauman, and Sallis (2004) reviewed 18 cross-sectional studies regarding the “relationships of objectively assessed and perceived environmental attributes” for “exercise and recreational walking, walking to get to and from places, and total walking” (Owen et al., 2004, p. 67). The authors found that perceptions about traffic were associated with both recreational and utilitarian walking (Owen, et al, 2004, p.72). In addition, they found that accessibility of destinations, including stores and parks, were associated with walking for particular purposes (Owen et al., 2004, p. 68). Route aesthetic attributes were found to be associated with recreational walking in some studies, but no studies found such an association with utilitarian walking (Owen et al., 2004, p. 72). The researchers called for more reliable measures of these environmental characteristics (Owen et al., 2004, p. 74). The call by Owen and his colleagues was heeded in the design of this

dissertation research, as discussed in the concluding summary of this literature review and outlined in detail in Chapter 3.

Tables 18, 19, and 20 summarize noteworthy contributions to the literature on correlates of walking. There is considerable evidence in this literature that trip distance, access to destinations, population density, sidewalks, amenities en route, and other physical characteristics of communities and streets are associated with an increased propensity to walk. It can be seen that many common threads emerge through the extensive review of the literature on determinants of walking. The consensus that emerges in this literature about particular factors is summarized at the end of this chapter and is built into the research design in this dissertation.

Table 2-18

Notable National-Level Research on Walking

Author(s)	Location and findings
Ham, Mererra, and Lindley (2005)	2001 (US) National Household Travel Survey Walking trips accounted for 21.2% of all trips less than one mile in length. In urban areas 39.3% of trips one mile or less in length were on foot, compared to 14.0% in rural areas.
Marcus (2008)	2001 (US) National Household Travel Survey About 78% of respondents did not walk on their survey day, but for those who did the average walk trip time was 15 minutes. There was a comparatively strong correlation between population density and walking. Those who lived less than one mile from work walked twice as often as those who lived more than 10 miles from work.
Agrawal and Schiemek (2007)	2001 (US) National Household Travel Survey This study found that 40% of walk trips in the US were for shopping, errands, and personal business; 20% were for recreation, 16% for access to or egress from public transport, and 11% for school or work commuting. Almost 70% of walk trips were four blocks or less in length. Utilitarian, but not recreational, walk trips increased as population density rose.
Kruger, Ham, Berrigan, and Ballard-Barbus (2008)	2005 (US) National Health Survey Only 6% of US adults walked for transportation and 9% for recreational purposes for at least 30 minutes five or more days each week.

Table 2-19

Notable Metropolitan Area Research on Walking

Author(s)	Location and findings
Greenwald and Boarnet (2001)	Portland, OR Metropolitan Area Amount of walking and Population density (+) Trip distance (-) Area walkability (+) Retail density (+)
Giles-Corti and Donovan (2003)	Perth, Western Australia Metropolitan Area There were individual, social, environmental, and physical influences on the amount of walking. Those living on a street with a sidewalk or shop on it were 75% more likely to achieve recommended amounts of walking than those who did not. Those who lived on a street with trees and without major traffic were 50% more likely to achieve recommended amounts of walking than those who did not.
Moudon et al. (2006)	King County (Seattle) Amount of walking and Residential population density (+) Smaller street blocks (+) Proximity to food and daily retail stores (+) Proximity to eating and drinking establishments (+)
Forsyth, Hearst, Oakes, and Schmitz (2008)	Minneapolis - St. Paul, MN Metropolitan Area There was more utilitarian, but less recreational, walking in higher density areas. Amount of walking and Sidewalks (+) Street lights (+) Traffic calming measures (+) Connected street patterns (+)
Rodriguez, Aytur, Forsyth, Oakes, and Clifton (2009)	Minneapolis - St. Paul Metropolitan Area and Montgomery County, MD Amount of walking and Population density (+) Access to destinations (+) Perceived difficulty in retail area parking (+) Ease of walking to transit stop, utilitarian walking (-)

Table 2-20

Notable Local-Level Research on Correlates of Walking

Author(s)	Location and findings
Lamont (2001)	Oakland, Albany, Berkeley, and Walnut Creek, CA Walking frequency was most influenced (inversely) by distance, age, student status, and neighborhood walkability. There was evidence of residential self-selection for the option of walking, even if individuals did not actually walk more after relocation.
Landis, Vattikuti, Ottenberg, McLeod, and Guttentplan (2001)	Pensacola, FL Study participants rated street segments. Amount of lateral separation from moving motor vehicle traffic had the highest positive association with sense of pedestrian safety and comfort. Sense of walking safety and comfort and Motor vehicle volume (-) Motor vehicle speed (-) # of through motor vehicle lanes (-) Width of outside lane (+) Width of shoulder or bike lane (+) Presence of sidewalk (+) Width of sidewalk (+) Width of buffer between street and sidewalk (+) Trees and other barriers between street and sidewalk (+) On-street parking (+)
Craig, Brownson, Cragg, and Dunn (2002)	22 neighborhoods in Quebec, Ontario, and New Brunswick The neighborhood physical environment was positively associated with propensity to walk to work. This relationship held true even while controlling for education, income, and degree of urbanization.
Brown, Werner, Amburgey, and Szalay (2007)	Salt lake City, UT Student raters used the Minnesota-Irvine Environmental Audit Instrument. The best rated routes had traffic safety, a pleasant social milieu, good aesthetics, and a diversity of destinations.
Wells and Yang (2008)	Southeastern US (various locations) This was a study of pre- and post-move walking of lower income women. Respondents walked more in neighborhoods with few or no <i>culs-de-sac</i> . Unexpectedly, land use mix was associated with less walking.

Why bike?

While walking may be the most important non-motorized mode of travel, the higher speed and therefore greater range of bicycling gives it more potential as an alternative to the automobile. What factors induce people to choose bicycling as a mode of travel? How important is the physical environment to this decision? There is a growing literature on this subject, much of which is applicable to the study of determinants or correlates of cycling on arterial streets.

Landis, Vattikuti, and Brannick (1997) developed a statistically calibrated model to predict the suitability or quality of non-central business district urban collector or arterial streets (excluding central business districts) for cycling (p. 119). The researchers used ratings provided by about 150 cyclists who rode a 27-kilometer course with a variety of street sections in the Tampa, Florida metropolitan area. Statistically significant variables in a linear regression model that explained about three-quarters of the variation in street section ratings given by the study participants included pavement surface condition, motor vehicle speed, and outside lane motor vehicle volume.

Harkey, Reinfurt, Knuiman, Stewart, and Sorton (1998) used ratings of over 200 study participants in Olympia, Washington, Austin, Texas, and Chapel Hill, North Carolina who viewed video clips of street sections to predict cycling comfort level (p. 53). Their statistical model, which included these variables and adjustment factors, explained 83% of the variation in “Bicycle Compatibility Index” scores:

- bicycle lane or paved shoulder present (+);
- width of bicycle lane or shoulder (+);
- width of curb lane (+);
- residential development along roadside (+);
- vehicle volumes (-);
- vehicle speeds (-);
- on-street parking (-);
- curb lane truck volumes (-);
- vehicle right turn volumes (-); and
- parking time limit (+) (Harkey et al, 1998, pp. 53-54).

Macbeth (1999) studied the effect of adding 40 km of bicycle lanes on Toronto streets from 1993 to 1998, often as part of conversion of the street cross-

section from two lanes in each direction to one in each direction with a left turn lane at signalized intersections (pp. 38-39). He notes that while motor vehicle traffic volumes are not affected by the installation of bicycle lanes, bicycle usage rises by varying amounts. In the case of Toronto, bicycle volumes rose from 4% to 42%, depending on street section, with an average rise of 24% after installation of bicycle lanes (Macbeth, 1999, p. 39). This study did not attempt to differentiate among street segments by land use, street network characteristics, population density, or other likely influences on bicycling demand.

Krizek (2006) conducted a stated preference survey to model the preferences of cyclists for on-street compared to off-street cycling facilities in Minneapolis-St. Paul. The researcher showed video clips of various bicycle facility types to 167 randomly selected University of Minnesota staff to elicit data for a model that predicted the odds of preferring a given facility type over others assuming equal travel time (Krizek, 2006, p. 312). He found that “the effect of travel time is negative, showing that people prefer shorter trips” (Krizek, 2006, p. 312). For a 20-minute bicycle ride, however, an on-street bicycle lane is worth an extra 16.3 minutes, the absence of on-street parking an additional .9 minutes, and an off-road bicycle path the addition of 5.2 minutes to the trip (Krizek, 2006, p. 313). The odds were also greater that the respondents would choose a more time-consuming route in summer than in winter in order to ride a preferred facility type and that neither income nor sex were significant influences on route decisions (Krizek, 2006, p. 312). This study is notable for its sophistication in identifying the marginal value in time of the trade-offs by cyclists making route choices based on facility type and season.

Pucher, Dill, and Handy (2010) reviewed 139 studies, both peer reviewed and otherwise, on the effects of various policy interventions on cycling demand. They concluded after review of this literature and evaluating 15 case studies of cities in Europe and the United States, that public policy can be effective in stimulating increases in bicycle use. This happens, however, only when a comprehensive, integrated approach is taken. Elements of such an approach are bicycle infrastructure, education and marketing to encourage bicycle use, land use planning that supports cycling, and automobile use restrictions (Pucher, et al., 2010, p. S122).

Additional research on bicycle demand is summarized in Tables 21 and 22. In general, this research has confirmed that the presence of bicycle facilities and constraints on automobile use are both associated with increased bicycle demand.

Both of these factors are embodied in the research design of the assessment of arterial streets that is the subject of this dissertation.

It is also clear from the review of bicycling determinants that there is not always universal consistency or agreement in the results. For example, some of the studies find little or no relationship between bike facilities and the level of cycling use and others find that traffic speed and volume of little consequence. The majority of studies, however, do report clear associations between such factors and cycling propensity. Overall, the literature points to considerable scope in further investigation in this area, especially at the street level.

Table 2-21

Notable North American Research on Bicycling Influences

Author(s)	Location and findings
Nelson and Allen (1997)	18 US cities Each additional mile of bikeway provided was associated with a 0.075% increase in bicycle share of work commuting.
Dill (2003)	35 US cities Bicycle demand and Bicycle lanes per square mile (+) Per capita spending on bicycle and pedestrian facilities (+) Number of vehicles per household (-)
Krizek and El-Geneidy (2005)	Minneapolis-St. Paul Metropolitan Area Neither on-street nor off-street bicycle facilities facilities had a statistically significant association with bicycle commuting.
Moudon et al. (2005)	King County (Seattle area), Washington Bicycle demand and Actual nearness to trails (+) Perceived access to trails and bicycle (+) Traffic speed, traffic volume, number of lanes, topographical conditions, and block size were not significantly associated with likelihood of cycling.
Hunt and Abraham (2007)	Edmonton, Canada Bicycle demand and one minute of cycling in mixed traffic is as onerous as 4.1 minutes in a bike lane or 2.8 minutes on a bike path and the availability of bicycle parking was equivalent to 3.6 minutes of cycling in mixed traffic.
Dill (2009)	Portland, OR Metropolitan Area A total of 166 cyclists were fitted with pda devices having GPS tracking capabilities. One-half of cycling trips took place on bike paths or bicycle (traffic calming mixed use streets designated as bicycle routes), although only 8% of the combined street and bikeway network were of these facility types.
Winters, Brauer, Setton, and Teschke (2010)	Vancouver, BC Metropolitan Area Cycling probability increased with flatter terrain, higher intersection density, fewer highways or arterials, traffic calmed streets, more neighborhood commercial land uses, and higher population density.

Table 2-22

Notable International Research on Bicycling Influences

Author(s)	Location and findings
Nankervis (1999)	Melbourne, Australia Bicycle demand and Daily temperature (+) Daily wind speed (-) Daily rainfall (-) Rain was most serious deterrent to cycling, followed by cold.
Rietveld and Daniel (2004)	103 Dutch cities A fall in bicycle trip time by 10% was associated with a 3.4% rise in bicycle trip demand and a fall in .3 stops per kilometer is associated with a 4.9% increase in bicycle trip demand. Bicycle demand and Price of car parking (+) Fewer hindrances en route (+) Fewer serious accidents (+) City size (-) Car ownership (-) Average slope of bicycle route (-)
Titse, Stronegger, Janschitz, and Oja (2005)	Graz, Austria Bicycle demand and Bicycle lane connectivity (+) Steep elevation (-) Perceived social support for cycling (+) The main barriers to cycling were physical discomfort and impracticality due to clothing or rain.
Wardman, Tight, and Page (2007)	UK (nationwide) Universal provision of bicycle lane network would increase bicycle mode share only from 5.8% to 9.0%. A £2 daily subsidy would increase the bicycle mode share to 10.9% and a £10 daily subsidy would increase the bicycle mode share to 28.0%.
Owen, N., et al. (2010)	Ghent, Belgium and Adelaide, Australia In Ghent, those who lived in more walkable neighborhoods were 2.5 times more like to cycle regularly for transport than those who did not. In Adelaide, those who lived in more walkable neighborhoods were 82% more like to cycle regularly for transport than those who did not.

As in the research on factors that may influence pedestrian demand, none of the studies on likely bicycle use determinants are both comprehensive in nature and focused on the street segment and its environs. Research for this dissertation has aimed to be both comprehensive and focused in order to explore in detail the context for both walking and cycling at the scale in which built environment and urban design each have the greatest impact.

Determinants of Public Transport Use

Question 11: what determines the demand for public transport on or adjacent to arterial streets?

Transit and lively streets.

Public transport has an important role in enlivening streets. Cappe (1987) viewed transit as animating street life:

The transit vehicle itself is a form of animation on the street. A sense of occasion is created when up to sixty people move past an area, some arriving, some departing, and some just moving through a place. The animation is experienced by pedestrians and bicyclists, as well as by people who look out of buildings that line the street. The stimulating array of colours, faces, and shapes add interest to the street scene. In addition, citizens on buses and streetcars act as a form of surveillance, thus greatly contributing to a city's livability (p. 291).

As such, bus and rail public transit can contribute to active, sustainable arterial streets. But why do people choose public transport as a travel mode?

Why take public transport?

Taylor and Fink (2002) reviewed the literature on factors that influence public transport demand. They note that there are two classes of determinants for public transport: internal factors, which include fares and service levels and external factors, which comprise socioeconomic, spatial, and public finance variables (Taylor & Fink, 2002, p. 6). The authors argue that since public transit is often an inferior good to the automobile, "the demand for transit service is largely determined by the supply of private vehicle access" (Taylor & Fink, 2002, p. 7). In addition, transit service area employment influences transit demand more than either per capita income or fare levels. Moreover, central business district employment influences public transport commuting levels more than does regional population. However, co-linearity among spatial variables and between these and socio-economic variables

make it difficult to sort out cause and effect (Taylor & Fink, 2002, p. 10). While the quantity of transit service influences transit demand, service provided in turn is “also determined by the ambient levels of transit service demand” creating endogeneity problems (Taylor & Fink, 2002, p. 13).

Chu (2004) modeled stop-level transit ridership in the Jacksonville, Florida area using socioeconomic, transit service, and automobile travel time metrics, as well as an assessment of the pedestrian environment in the environs of bus stops (p. 17). The pedestrian environment assessment variable was based on a composite score for the following factors: traffic signal in vicinity (yes/no), median type, number of traffic lanes, pedestrian street crossing delay, PM peak hour traffic volume, and presence of a continuous sidewalk (yes/no) (Chu, 2004, p. 17). The researcher found that, “the pedestrian environment, accessibility measures to population and employment, interactions with other modes, and competition from other stops all play a statistically significant role in average weekly boardings” (Chu, 2004, p. 44). These variables have been found to influence bus transit demand at the stop level:

- median household income in stop catchment area (-);
- population within walking distance (+);
- employment, stop catchment area (+);
- # zero vehicle households, stop catchment area (+);
- # persons <18 years old, stop catchment area (-);
- # persons 18-64, stop catchment area (+);
- # females, stop catchment area (+);
- # hispanic, stop catchment area (+);
- # white, stop catchment area (+);
- transit level of service within one minute walk (+);
- transit level of service within two to five minute walk (+);
- pedestrian-friendliness factor (+);
- population “up and downstream” of stop” (+);
- employment “up and downstream” of stop (+); and
- number of other bus stops, catchment area (-) (Chu, 2004, p. 43).

Research on factors that influence demand for public transit has identified several key variables: transit service levels, population and employment density, and constraints on auto use. Table 23 shows findings from other notable studies of public

transport demand correlates. Findings from the stop-level research inform studies of transit demand at the level of the individual street section, including work undertaken in this dissertation. Nevertheless, none of the research discussed or summarized puts demand for public transport in the holistic context of the multimodal arterial street and its environs.

Table 2-23

Notable Research on Stop-Level Public Transport Demand

Author(s)	Location and findings
Ewing (2001b)	Sarasota County, FL Bus stop visual preference and Bus shelter (+) Bus bench (+) Shade from trees or roof overhang (+) Vertical curb at stop (+) Trees along route to stop (+)
Johnson (2003)	Minneapolis, MN (Central Business District) Public transport stop level demand and Automobile access (-) Population <16 years of age (+) Population density, block group level (+) Multifamily housing between .125 and .25 mile from stop (+) Retail land use in proximity (+) Retail-commercial land use mix (+) Multifamily housing less than .25 mile from stop (-) Express bus service to stop (-)
Kuby, Barranda, and Upchurch (2004)	9 US cities/ Light rail stop level demand and Employment density within walking distance (+) Population density within walking distance (+) Bus lines connecting to light rail stop (+) Terminal station (+) Transfer station (+) College enrollment (+) Airport proximity (+) Park-and-ride spaces (+) Bus connections (+) Relative centrality of station (+) % of metro area served by light rail system (+) % renters within walking distance (+)
Cervero, Murakami, and Miller (2009)	Los Angeles County/ Bus rapid transit (BRT) stop level demand and # daily BRT buses (+) # daily feeder buses (+) # daily feeder trains (+) Population density within .5 mile of stop (+) BRT park-and-ride lot spaces & dedicated BRT lane (+) Population and employment density & dedicated BRT lane (+)

Access to Public Transport

Question 12: what determines the choice of access mode to public transport on or adjacent to arterial streets?

Principles.

Why do people choose one mode over another mode of access to public transport? How do these choices contribute to or detract from active, sustainable streets? The Bay Area Rapid Transit District (BART) has promulgated a set of principles to guide planning for access to stations (Millard-Ball, 2003). These include provision of pedestrian routes to and from stations that are “safe, direct, and appealing”; giving passengers a “strong sense of security” to, from, and at stations; ensuring that passengers can “quickly and easily orient themselves”; plan “direct, safe, and well-marked routes” for walking or cycling to and from stations; taking care to “prioritize feeder transit service”; and “collaborating with local communities and developers to promote transit oriented development close to stations” (Millard-Ball, 2003, pp. 3.3-3.10). These principles are broadly applicable to walking, cycling, and using public transport along an arterial street to access public transport services.

Walk and bike access to public transport.

Hass-Klau (2003) described a three-way relationship between walking and public transport. While both the demand for walking as a single mode and the average distance walked will decline due to higher frequency and “penetration” of public transport services, walking trips will increase due to more demand for access to public transport stops and stations. Secondly, reduction in public transport services will increase the amount of walking in the short term, but some of this increase will attenuate in the longer term as more people buy cars in response to loss of public transit service. Thirdly, replacing bus with faster light rail service and fewer stops may result in fewer, but longer walk trips to transit (Hass-Klau, 2003, p. 86).

Ewing (1996) prepared a checklist of pedestrian- and transit-friendly design for transit served corridors and station environs. The author’s list appears in Table 24.

Table 2-24

Design Elements for Walking and Public Transport

Essential	Highly desirable
Medium to high density	Grid-like street networks
Mix of land uses	Supportive commercial uses
Short to medium length blocks	Traffic calming along street
Transit routes every half-mile	Closely spaced street trees
Two to four lane streets (with "rare" exceptions)	Minimize "dead space" and visible parking
Continuous sidewalks, "wide enough for couples"	Nearby parks and other public spaces
Safe pedestrian crossings	Small scale buildings or articulated big buildings
"Appropriate" pedestrian buffering from traffic	"Classy-looking" transit facilities
Street-oriented buildings	

Note. Adapted from Ewing, 1996, *Pedestrian- and transit-friendly design: a primer for smart growth*, pp. 2-18.

Agrawal, Schlossberg, and Irvin (2008) surveyed 328 weekday walkers to two rail stations in the San Francisco Bay Area and three in Portland, Oregon. Nearly all (99%) of respondents reported choosing their walk route to the station because being "the shortest route" was either "very important" (17%) or "somewhat important" (82%) (Agrawal et al., 2008, p. 92). Subsequent GIS plotting of respondents' origins and station destinations validated this preference for minimizing walk distance. Mean reported walk distance was .47 miles or .76 kilometers. The authors observe that "pedestrians walk considerably farther to access rail stations than commonly assumed" (Agrawal et al, 2008, p. 93). Consequently, "designers and planners should focus their attention on arterial and collector streets", the sidewalks along and crosswalks across which often provide the shortest walk trip distance to and from public transit stations, to increase pedestrian safety and comfort (Agrawal et al., 2008, p. 96).

Research on access to public transport has identified a number of access route characteristics associated with increased propensity to access public transportation by non-motorized travel modes. These characteristics include distance to a transit station or stop, pedestrian as well as bicycle friendliness of the route, land use mix,

impediments to car use, and both population and employment density. Tables 25 and 26 show research findings on access to public transport.

Table 2-25

Notable US Research on Access to Public Transport

Author(s)	Location and findings
Loutzenheiser (1997)	<p>San Francisco Bay Area (34 BART stations)</p> <p>Decision to walk to station and</p> <p>Distance (-)</p> <p>Car availability (-)</p> <p>Total length of arterial streets with two or more travel lanes in each direction (-)</p> <p>Grid street layout (-)</p> <p>Median age (+)</p> <p>Freeway proximity (-)</p> <p>Retail land use dominant (+)</p> <p>Land use mix (+)</p> <p>Work or school trip (+)</p> <p>Male (+)</p> <p>Every .5 kilometer added to a walk trip was associated with a 50% fall in likelihood of walking to station.</p>
Cervero (2001)	<p>San Francisco Bay Area and Montgomery County, MD</p> <p>Walking was the dominant access mode to Bay Area BART stations for distances less than .625 mile.</p> <p>Public transport was the most important access mode for distances from .625 mile to one mile.</p> <p>Auto park-and-ride was dominant beyond a one- mile radius of stations.</p> <p>Decision to walk to station and</p> <p>Employment density within .5 mile of a station (+)</p> <p>Population density within .5 mile of a station (+)</p> <p>% land area in residential use within .5 mile of a station (+)</p> <p>Land use mix (+)</p> <p># park-and-ride spaces at a station (-)</p> <p>Transit service levels within .5 mile of a station (-)</p> <p>Terminus or transfer station status (+)</p> <p>An increase of 10 households per acre was associated with an 11.3% rise in station access trip by walking.</p> <p>An increase of 10 additional jobs per acre was associated with a 3.33% rise in station egress trips by walking.</p>

(continued)

Table 2-25

Notable US Research on Access to Public Transport (continued)

Author(s)	Location and findings
	<p>Walk access to Montgomery County, MD rail stations and Ratio of sidewalk miles to road miles(+)</p> <p>Land use mix (+)</p> <p>Intersections per square mile (+)</p> <p>Walk egress and Distance (-)</p> <p>Median street width (-)</p>
Schlossberg and Brown (2004)	<p>Portland OR Metropolitan Area (11 TOD sites)</p> <p>"Impedance-based" measures of intersection density showed actual access to stations varied among stations and within areas at .25 mile and .5 mile radius from stations.</p> <p>Impedance-based intersection density was derived by subtracting arterial street intersections.</p>
Park (2008)	<p>Mountain View, CA</p> <p>Four physical environment attributes most influence the decision to walk to the train station: sidewalk amenities, traffic, street scale and enclosure, and landscaping elements.</p>
Brown and Werner (2009)	<p>Salt Lake City (new light rail stops)</p> <p>Pre-existing favorable attitudes toward rail were insufficient to motivate new riders to walk long distances to access light rail.</p> <p>Supportive attitudes had limited influence when the walking environment to access rail stop was not supportive.</p>

Table 2-26

Notable International Research on Access to Public Transport

Author(s)	Location and findings
Martens (2004)	Netherlands, Germany, UK Most bicycle access trips to transit were within the 2 to 5 kilometer range. Longer bicycle access trips were taken for the faster rail transit modes. The bike access share was higher in The Netherlands for work or school trips and for rail compared to bus.
Boon, Tong, and Olszewski (2005)	Singapore Transit passengers were willing to walk further for rail than for bus service. The quality of walking routes affected perceptions of route quality and walking comfort.
Sulaksono and Olszewski (2005)	Singapore This study defined an "equivalent walking distance" that accounted for impedances. Walking distance was the most significant influence on choice to walk to a transit station. Men were more likely to walk to a station than women. The effort in crossing a street equivalent to 55.4 meters of walking along a street. Crossing a car park or access road was equivalent to a 36.31 meter walk.
Estupiñán and Rodríguez (2008)	Bogotá, Columbia The research determined "local accessibility" around each BRT stop to be a 250-meter buffer. BRT stop-level demand and "Walking supports" (+) Barriers to car use (+) Transit supply (+) Safety and security (+) "Walking supports" were defined as perceived sidewalk quality and pedestrian amenity.

This research approach in this dissertation has been informed by the salient findings in the literature on determinants of mode choice for accessing public transport. The variables culled from the literature are summarized at the end of this chapter and described in operational terms in Chapter 3.

Walking and Cycling Safety

Question 13: what determines the safety of walking and cycling on arterial streets?

Safety in two senses.

Whether en route to a transit station or otherwise, what makes for a safe walk or bicycle trip? There are two aspects to safety as it pertains to walking and cycling: traffic and personal. While both have received scholarly attention, there is more evidence about how traffic conditions and engineering measures influence traffic safety for walkers and cyclists than how actual or perceived personal safety concerns affect active travel.

Traffic safety engineering measures.

Retting, Ferguson, and McCartt (2003) surveyed the literature on traffic engineering measures to reduce motor vehicle and pedestrian crashes. They found three classes of safety counter-measures: speed control, separation of pedestrians from motor vehicles; and measures to increase pedestrian visibility and conspicuity. They concluded that “modification of the built environment can substantially reduce the risk of pedestrian-vehicle crashes” (Retting et al., 2003, p. 1456). Controlling motor vehicle speeds is especially important since “slower speeds give motorists more time to react and can lessen injuries when crashes do occur” (Retting et al, 2003, p. 1457). The following traffic engineering counter-measures have been recommended for their potential to increase pedestrian safety:

- single lane roundabouts;
- exclusive pedestrian phase on traffic signal;
- all vehicle stop traffic signal phase;
- automatic pedestrian detection at traffic signals;
- in-pavement crosswalk lights;
- signs and pavement markings for pedestrians;
- pedestrian over-crossings and under-crossings;
- sidewalks;
- median refuge islands;
- curb extensions;
- barriers to channel pedestrians away from dangerous crossings;
- recessed vehicle stop bar at crosswalks;

- increase intensity of crosswalk lighting;
- angle parking (facing traffic); and
- relocate bus stops from near side to far side of intersection (Retting et al., 2003, pp. 1459-1462).

Pucher and Dijkstra (2003) examined measures taken in the Netherlands and Germany to provide safer walking and cycling environments. American pedestrians are three times more likely to be killed in a motor vehicle crash than those in Germany and six times more likely than Dutch pedestrians. American cyclists are twice as likely as German cyclists and three times as likely as Dutch bicyclists to be killed. Moreover, pedestrians in the US are twice as likely to be injured as pedestrians in Germany and four times more likely than Dutch pedestrians. In addition, American cyclists are 8 times and 30 times more likely to be injured than German and Dutch cyclists, respectively (Pucher & Dijkstra, 2003, pp. 1512-1513). He points out that public policy in Germany and the Netherlands favors auto-free zones; wide, well-lit sidewalks; pedestrian-actuated crossing signals; “Zebra” striped pedestrian crossings, often raised; extensive bike path and bikeway networks, including bicycle-priority streets on which bicycles have right-of-way; and lower general speed limits for automobiles (Pucher & Dijkstra, 2003, p. 1513).

Jacobsen (2003) examined crash injury data from California, Denmark, the UK, the Netherlands, and elsewhere in Europe and concluded that “the likelihood of an injury is not constant but decreases as walking or bicycling increase (p. 207). In summary, “multiple independent datasets” that are “consistent across geographic areas” show that the total number of pedestrians or bicyclists struck by motorists changes with the 0.4 power of the change in pedestrian volumes, so there is “safety in numbers” (Jacobsen, 2003, p. 208).

Ewing and Dumbaugh (2009) reviewed the literature on the relationship between the built environment and traffic safety. The authors found that on-street parking, parking turnover, number of driveways and side streets, vehicle turning movements, and urban area roadway widths were associated with higher vehicle crash rates. Raised medians were associated with both lower vehicle and lower vehicle-pedestrian crash rates. One lane roundabouts were related to lower vehicle crash rates, but had an indeterminate effect with respect to pedestrian – motor vehicle crash rates (Ewing & Dumbaugh, 2009, pp. 355-359).

Table 27 summarizes other research findings on traffic safety. Notable findings include the benefits of protected crosswalks, slower motor vehicle speeds, landscape and other buffers, and fewer traffic lanes, and pedestrian-oriented land uses. All of these variables in some form or other were woven into the research design of this dissertation.

The presence of pedestrians and cyclists is essential for active, sustainable streets. Yet at the same time non-motorized modes of travel are at greater risk on streets than are the motorized modes. As such, investigation of the empirically-verifiable and subjectively-felt safety of walkers and bicyclists is a critical part of any study of street activity and sustainability.

Table 2-27

Notable Research on Traffic Safety

Author(s)	Location and findings
Wachtel and Lewiston (1994)	Palo Alto, CA Wrong-way riding increased the risk of a crash by a factor of 3.6. Sidewalk riders increased the risk of a crash by a factor of 1.8.
Knoblach, Nitzburg, Siefert (2001)	11 intersections in Sacramento, CA, Richmond, VA, Stillwater, MN, and Buffalo, NY Crosswalk marking reduced the speed of approaching vehicles when a pedestrian was present in the crosswalk. Crosswalk markings did not have any statistically significant effect on the "aggressive" behavior of pedestrians or the yielding behavior of drivers. There was no evidence that crosswalk markings made pedestrians less vigilant.
Ossenbruggen, Pendharkar, and Ivan (2001)	Small towns in Stafford County, NH Mixed use streets were less hazardous than single use residential or commercial streets.
Chu, Guttenplan, and Baltes (2003)	48 street blocks in Tampa, FL The probability of crossing a street at a given location was inversely related to the walking distance along a street to the next crosswalk, the walking distance across the street, and width of the shoulder or bike lane. The probability of crossing a street at a given location was positively related to presence of crosswalk markings, a traffic signal, and a pedestrian signal.
Mok, Landphair, and Naderi (2003)	8 Texas cities Crash rates were lower on street and road sections with roadside landscaping, median landscaping, or sidewalk widening and tree planting.
Naderi (2003)	Galveston, TX and Toronto Curb side or median landscaping was associated with a 5% to 20% reduction in accidents and increased pedestrian activity.

(continued)

Table 2-27

Notable Research on Traffic Safety (Continued)

Author(s)	Location and findings
Dumbaugh (2005)	Orlando, FL This study examined 5 years of crash data for two .9 mile sections of State Road 50. The section with roadside buffers for pedestrians, on-street parking, narrower lane widths, and a 1.5 to 2.0 foot (.3 to .45 meter) off-set from the street to fixed objects had fewer mid-block crashes, crash injuries and fatalities, pedestrian and bicyclist injuries, and roadside object injuries.
Zegeer et al. (2005)	US There was no difference in crash rates between marked and unmarked crosswalk locations along 2-lane roads. There were higher pedestrian crash rates at marked locations without additional protection across 4-lane roads with AADT of greater than 12,000.
Fitzpatrick , et al. (2006)	42 field studies in 7 US states Motorist stop compliance and Traffic signal with red indication (+) # of travel lanes (-) Posted speed limit (-)
Dumbaugh and Rae (2009)	San Antonio, TX Each additional mile of arterial roadway increased the number of injurious crashes by 17%. Each additional "arterial-oriented" land use associated with a 1.1% rise in crash injuries. Each added "big box" store increased crash injuries by 4.0%. Each additional pedestrian scale retail and commercial use was associated with a 3.4% decrease in crash injuries. Fatal crash rates increased with arterial street miles and decreased with number of 3- and 4-legged intersections.

Personal security.

Does fear for personal security deter active travel? Loukaitou-Sideris (2006) reviewed the literature pertaining to the effect of neighborhood safety and security on walking and other outdoor physical activity by residents. She found mixed results, attributable to methodological issues and to the interaction among variables, particularly since the relationship “between perceived risk, fear, and (in) activity

seems to be quite nuanced and modifiable by factors that vary among different individuals, social groups, and neighborhood settings” (Loukaitou-Sideris, 2006, p. 222).

Foster and Giles-Corti (2008) also reviewed the literature on the relationship between safety and constrained physical activity to find mixed support in quantitative studies (p. 241). They conclude that there is insufficient evidence to date to relate crime rates or fear of crime to probability of physical activity in neighborhoods and call for longitudinal studies that “would assist in drawing conclusions about causality” (Foster & Giles-Corti, 2008, p. 249).

Ferrell, Mathur, and Mendoza (2008) studied the relationship between neighborhood crime rates and mode choice at the traffic analysis zone level in seven San Francisco Bay Area cities: San Francisco, Oakland, Berkeley, Concord, Santa Clara, Sunnyvale, and Walnut Creek. The authors found an association between “high vice and vagrancy crime rates” and a lessened probability of taking public transport in suburban cities for both work trips and non-work trips. Moreover, high property crime rates in urban and inner suburban cities were related to a lower probability of walking to work and high violent crime rates were also associated with a lower probability of walking to work. In addition, high property crime rates in San Francisco were related to a lessened probability of walking for non-work purposes (Ferrell et al., 2008, p. 2).

Bennett et al. (2007) studied physical activity among 1,188 primarily minority residents of 12 low-income housing complexes in metropolitan Boston. Study participants were fitted with a pedometer and were given an attitudinal survey. The researcher found no association between reports of both male and female respondents about daytime safety and measured physical activity, but “women who reported feeling unsafe (versus safe) at night showed significantly fewer steps per day” (Bennett, et al, 2008, p. 1599).

Theoretical Foundations of “Sustainable”, “Active” Arterial Streets

Question 14: what is the theoretical basis for study of “sustainable”, “active” arterial streets?

Theory informing research.

All of the studies described in this literature review have explicitly or implicitly relied upon certain theoretical assumptions and foundations in the conduct of their empirical investigations. Until now the theoretical framework for research

into active, sustainable streets has not been specifically stated. Likewise, the research design for this dissertation, while drawing heavily on observed empirical results in a vast collection of previous studies, also assumes certain theoretical underpinnings, which need to be made explicit. This section attempts to draw together the key theories that support research into sustainable, active streets.

How does theory inform research in active travel and sustainable streets? Handy (2005) observes that “researchers must rely on theory, empirical evidence, and intuition in choosing which relationships to target for study” on the role of the built environment on levels of walking, cycling and other physical activity (p. 6). Crane (2000) highlights “the complexity of travel behavior, together with the difficulty of isolating and explaining the role of individual features of the built environment” (p. 11). In their review of literature on the influence of land use and built form on mode choice, Riley and Landis (2002) found evidence suggesting that “built-form characteristics and mode choice are correlated while controlling for a variety of socio-demographic factors”. The authors go on to point out that while these associations “are significant and in the direction suggested by theory” they are also, nevertheless, “generally moderate in magnitude with the exception of trips for access to transit” (Riley & Landis, 2002, p. 42). They also describe utility theory, a cornerstone of travel demand research as rooted in decision-making by individuals:

Individuals are assumed to make travel decisions to obtain the greatest amount of satisfaction (i.e. utility) possible within the constraints imposed by their income, household role, time, location, and transportation supply. An individual’s preferences determine how the various characteristics of potential choices are evaluated in order to arrive at the utility-maximizing choice (p. 10).

Utility theory.

Hensher and Brewer (2001) summarize an individual’s time utility function as simply (p. 85):

$$U = U(x_1, T_1, x_2, T_2, \dots, x_n, T_n), \quad (2.1)$$

where $\{T_1, \dots, T_n\}$ is time spent in activities 1 to n and

$\{x_1, \dots, x_n\}$ are market goods and services consumed jointly with time in the activities

Travelers as consumers are subject to both time and budget resource constraints. The consumer’s optimization problem is maximizing utility subject to these constraints.

There is a “shadow price” entailed in time allocation, which is the opportunity cost of its use in one activity compared to the economic value of its use in another (Hensher & Brewer, 2001, p. 87).

Handy (2005) writes that the utility maximizing approach to understanding the determinants of travel led to the formulation of “a function for utility that included mean utility reflecting representative tastes, plus a stochastic or ‘random’ component reflecting unobservable variations in tastes and unobserved attributes of choices” (p. 8). As a result, “utility is assumed to be a linear function of a series of attributes of the choice, each with a coefficient that reflects the relative importance of that attribute” (Handy, 2005, p. 8).

Ben-Akiva and Lerman (1985) applied this utility-maximizing model to the problem of “discrete choice” of travel opportunities faced by individuals. Travel choice has four elements: the decision-maker, the alternatives (or “choice set”), the attributes of the alternatives, and a decision rule (Ben-Akiva & Lerman, 1985, pp. 33-35). The attributes of an alternative comprise a vector of values. The decision rule is a product of “the internal mechanisms used by the decision-maker to process the information available and arrive at a unique choice” (Ben-Akiva & Lerman, 1985, p. 35). The travel choice set is determined by “income and time budgets and other external restrictions” (Ben-Akiva & Lerman, 1985, p. 48). The utility function pertaining to the model of travel choice behavior is as follows (Ben-Akiva & Lerman, 1985, p. 48):

$$U_{in} = (U_{z_{in}}, S_n), \quad (2.2)$$

where z_{in} is a vector of the attribute values for alternative i as viewed by decision maker n and S_n is a vector of characteristics of the decision maker n

For Ben-Akiva and Lerman, utility is “an index of attractiveness” which a “decision maker attempts to maximize through his or her choice”. As such, “the supposition of a single index is based on the notion of trade-offs, or compensatory effects, that a decision maker is using explicitly or implicitly in comparing different attributes” (Ben-Akiva & Lerman, 1985, p. 37). Such decisions are made under conditions of “bounded rationality” in which human beings must operate under “limited information processing capabilities” (Ben-Akiva & Lerman, 1985, p. 38). Travel and other consumer choices are the result of an effort to maximize utility in the comparison of alternatives, as follows (Ben-Akiva & Lerman, 1985, p. 44):

$$U_1 = -\beta_1 t_1 - \beta_2 c_1 + \beta_3 o_1 \quad (2.3)$$

$$U_2 = -\beta_1 t_2 - \beta_2 c_2 + \beta_3 o_2 \quad (2.4)$$

$$U_3 = -\beta_1 t_3 - \beta_2 c_3 + \beta_3 o_3 \quad (2.5)$$

where (U_1, \dots, U_n) are sums of utility to be obtained from individual choices in a choice set; (t_1, \dots, t_n) are time costs associated with each choice; (c_1, \dots, c_n) monetary costs; (o_1, \dots, o_n) decision maker tastes and preferences; and $(\beta_1, \dots, \beta_n)$ coefficients giving weights to each of these variables.

Mokhtarian and Salomon (2001) take issue with the “tenet that travel is a ‘derived demand’” a notion “which pervades modern transportation planning” by pointing out that some travel is undertaken for its own sake (p. 696). They define “undirected travel” as “movement through space for which the destination rather than the travel is ancillary” (Mokhtarian & Salomon, 2001, p. 698). This form of travel comprises such activities as recreational walking, jogging, cycling, skating, skateboarding, horseback riding, hiking, skiing, etc. (Mokhtarian & Solomon, 2001, p. 697). Moreover, “the beauty or novelty or some other characteristic of a particular route may motivate an individual to travel that route even if it is not the shortest way to a desired destination” (Mokhtarian & Solomon, 2001, p. 699). The authors contend that there are three components of the utility of travel: the destination itself, activities that can be conducted while traveling, and the activity of travel itself (Mokhtarian & Salomon, 2001, p. 701).

These researchers surveyed approximately 1,900 people residing in San Francisco Bay Area communities and found that “more than three-quarters of the sample reported sometimes or often traveling ‘just for the fun of it’” (Mokhtarian & Solomon, 2001, p. 716). For Mokhtarian and Solomon, this provides evidence “to support the existence of a positive utility for travel”, although “the precise distribution of that utility across the population is uncertain” (p. 705). Mokhtarian (2005) notes that, “even in the familiar daily travel context, a variety seeking orientation” influences choice of routes” (p. 93). She argues that while “information and communications technologies are blurring the distinction between activities and travel”, the construct that travel is a derived demand “still serves as a useful first-order approximation in many countries” (Mokhtarian, 2005, pp. 95-96).

Active, sustainable streets are host to both purpose-driven travel and travel for its own sake. This dissertation research assumes that characteristics of both the

travel destination and the travel route influence the activity on and sustainability of arterial streets.

Theory of planned behavior.

The “theory of planned behavior”, which focuses on attitudes and social norms has been advanced as a theoretical framework for understanding travel decisions (Handy, 2005, p. 13). Psychologist Icek Ajzen (1991) argued that attitudes and norms have predictive power:

Attitudes toward the behavior, subjective norms with respect to the behavior and perceived control over the behavior are usually found to predict behavioral intentions with a high degree of accuracy. In turn, these intentions, in combination with perceived behavioral control, can account for a considerable proportion of variance in behavior (p. 26).

Bamberg, Ajzen, and Schmidt (2003) applied the theory of planned behavior in a study of change in travel choices made by 1,316 college students at the University of Giessen in Germany before and after introduction of a prepaid bus ticket. Their research methodology included surveys of respondents’ attitudes, beliefs, and sense of behavioral control regarding travel choices, as well as travel behavior both before and after introduction of the bus subsidy. They found that “choice of travel mode is largely a reasoned decision that can be affected by interventions that produce change in attitudes, subjective norms, and perceptions of behavioral control” (Bamberg et al., 2003, p. 175).

The authors describe the theory of planned behavior as guiding human action in three ways: “beliefs about the likely consequences of the behavior (behavioral beliefs), beliefs about the normative expectations of others (normative beliefs), and beliefs about the presence of factors that may further or hinder performance of the behavior (control beliefs)” (Bamberg et al. 2003, p. 175). The authors note that the intervention of the prepaid bus ticket produced changes in “attitudes, subjective norms, and perceptions of control” that were “sufficient to disrupt the relation between frequency of past bus use and later behavior”, thus overcoming past travel habits (Bamberg et al., 2003, p. 183). The existence of “new information, if relevant and persuasive, can ... influence later behavior”. This means that “human social behavior, although it may well contain automatic elements, is based on reason” (Bamberg et al., 2003, p. 186).

Aarts, Verplanken, and van Knippenberg (1997) tested the strength of travel habits as a contrast to planned behavior in a study of the bicycling habits of 82 students at the University of Nijmegen in the Netherlands. He found that “strong habit” student cyclists “used fewer attributes about the circumstances under which the trip had to be made” and were also “more selective in using the information of the attributes of choice options” than was the case with “weak habit” students (Aarts, et al., 1997, p. 5). Research undertaken for this dissertation has been predicated on the idea that changes in street design and streetscape can induce changes in travel behavior. These behavioral changes can induce people to overcome the inertia of previous travel behavior and thus create more active, sustainable arterial streets.

“Theory of the built environment”?

What about the built environment itself as a catalyst for behavioral change? For Handy (2005), the “theory of the built environment”, or the mechanisms by which it affects behavioral choices and patterns, at present is only “a loose assembly of ideas about specific characteristics of the built environment that influence behavior in public spaces” and “not explicitly a behavioral theory” (p. 1). Any theory regarding how the physical environment influences physical activity, including walking and cycling, needs be “based on the existing urban design literature and travel behavior theory” (Handy, 2005, p. 3).

While Handy’s judgment is summary, it may also be accurate. At its current stage of development, urban design theory does not appear to have evolved into a coherent, testable set of propositions sufficient to guide research into travel behavior, as evidenced by this review of the literature. The review has found many disparate results and approaches to a wide variety of issues and situations. All were meant to explore the effects of different physical features on the level of travel by different modes.

Theoretical Assumptions.

This dissertation has relied on travel behavior theory, the theory of planned behavior, and the urban design literature in formulating both a set of research questions and a research strategy. The research undertaken in this dissertation assumes that each street user seeks to maximize his or her net utility regarding activities that are related to street use and any travel associated with these activities. The research also assumes that travel behavior is largely planned behavior, subject to change based on changes in information available to and perceptions by travelers of

travel opportunities and the travel environment. This work has also been informed by the growing literature on the impacts of the built environment on travel, especially at the scale of the street and its environs.

Chapter 3 provides detail on the methodological approach used in undertaking the field work and data analysis built upon the extensive scholarly framework discussed in this chapter. As discussed in Chapter 3, this literature review produced, through a largely inductive process, the set of potential influence variables to test on arterial street activity and sustainability.

Defining a Sustainable Arterial Street

Question 15: to what extent can a working definition of a sustainable arterial street be developed after answering the foregoing questions?

Attributes of a sustainable arterial street.

There are several core characteristics of the sustainable arterial street that can be derived from the scholarly literature. Sustainable arterial streets support use of low-emission, energy-efficient, and space-efficient modes of transport. These streets foster both social interaction and economic vitality, as well as create visual interest for all who make use of them. Sustainable streets offer the benefits of natural elements, especially trees and permeable surfaces, designed into their right-of-way. Users of sustainable arterial streets are safer from traffic and from crime.

Working definition of a sustainable arterial street.

These elements can be distilled into a working definition of a sustainable arterial street, as follows: “A sustainable arterial street gives priority to energy-efficient, low-emission or no-emission modes of transport; supports social and economic vitality; fosters traffic and social safety; incorporates natural elements; and creates visual interest for its users.”

Conclusion

Framework for answering the primary question for the literature review: what is the state of knowledge regarding “sustainable”, “active” streets?

The literature review in the preceding sections has set out the complexities involved in any comprehensive investigation of the nature and use of arterial streets. As what occurs on streets takes place at the junction of the physical and the behavioral, this complexity is practically pre-ordained. There is an expansive, multidisciplinary literature on sustainable, active streets. Despite this, the very

breadth, and often contradictory nature, of this scholarly record seems at times to reveal complexities more than answer questions.

Nevertheless, there is a sense or thread in much of this literature on the streets, to borrow the title of an article by the American urban designer Elizabeth Macdonald (2007), of the street as “wasted space, potential place”. There seems little doubt that streets have had and continue to have an important role in the life of cities and those who live in cities. Streets clearly have potential to contribute to urban sustainability. This potential reflects the distance to be covered from the often disappointing actuality of contemporary arterial streets to their bright, shining possible future as sustainable, active public spaces. Future research into this potential will need be both qualitative and quantitative, as is fitting for a subject located at the intersection of human behavior and physical infrastructure.

In the spirit of the scholarly record explored in this chapter, future research on the sustainability of arterial streets also needs to be both multi-method and interdisciplinary if it hopes to reveal the complex, interwoven pattern of effects that flow from street design and street use. Just as sustainability is more an elusive ideal than an achievable end state, scholarship on the sustainability of arterial streets may progress toward but never arrive at a metaphorical “terminal station”. Located at the juxtaposition and responding to dynamic systems of transportation, land use, urban design, and human behavior, arterial streets themselves will not remain static. The study of streets is therefore necessarily also an inquiry into the evolution of cities and their inhabitants, technology, commerce, leisure, and culture.

The eight research questions investigated in this dissertation were derived from my own experience as a practicing urban and regional transportation planner as well as extensive reading in the literature on streets and the influences on street use. The literature contains both useful evidence and a number of gaps that need to be filled to answer these eight research questions. In this important sense the questions were arrived at inductively in the course of professional practice, then refined and supplemented through study. They represent my own, heuristic, view of what are the most important questions in scholarship on active, sustainable arterial streets. The following is a thumbnail description of the judgments and gaps in the scholarly literature on these topics, through the lens of the eight original research questions posed in the first chapter of this dissertation.

"Active" streets.

1. *What are "active" streets and how can "activity" on streets be measured?*

Streets are active to the extent that they support a variety of purposes, some requiring movement and some more passive. Activity on streets can be observed directly as well as discerned from the opinions of street users. Methods and data to do so vary widely. In the literature to date, street activity is a necessary, but not sufficient, condition for street sustainability.

2. *To what extent does continuous street (building) frontage contribute to "active" streets and, if so, how can its contribution be measured?*

The literature judges continuous frontage as a desirable but not sufficient condition that can contribute to street activity. The nature of the land uses on the street, the apportionment of space in the street right of way, motor vehicle operations, and the transport choices provided all have a more direct influence on street activity. At the extreme, continuous street frontage can resemble a mere Potemkin village or Hollywood stage set without these activating ingredients.

Street design and street function.

3. *To what extent does street design (geometry, partitioning of space) affect street use and, if so, how?*

The literature gives an incomplete answer to this question. There has been inquiry into the effects of street re-design to calm traffic and/or induce more use of alternatives to the private motor vehicle. Beyond this, the literature becomes more spare and tentative.

4. *What are "complete streets" and how can "completeness" be measured?*
Street completeness has come to be understood in the literature as inclusion of pedestrian, bicycle, and in some cases public transport space within street rights-of-way. This consensus understanding does not extend to other street uses however, including space for nature. Nor does it consider degrees of completeness or the implications for trade-offs among potential street purposes. Measurement of completeness is in an embryonic stage.

5. *To what extent does dedicated space for pedestrians, cyclists, and public transport users contribute to the amount of walking, bicycling, and public transport use along streets?*

There is only limited understanding of, much less consensus on, this question in the scholarly record. Comprehensive field data, as well as street user survey findings, are scarce in the literature to date.

6. *What is the relationship, if any, between “space for nature” and the transport and other functions of streets?*

Once again, there are limited findings in the scholarly or practitioner literatures to shed light on this question. What exists is mainly focused on the benefits of permeable surfaces in the street right-of-way and the protective value of tree canopy in the planting strip between the street and the sidewalk.

7. *How does a street’s aesthetic appeal affect street use, if at all?*

There is scholarly evidence only that aesthetic appeal translates to increased retail sales and commercial property values, as well as user willingness-to-pay for an aesthetically pleasing street (and outdoor) environment.

“Sustainable” streets.

8. *How can the “sustainability” of urban commercial streets be assessed?*

The literature on this question is nascent. While there have been promising forays into this domain, there is much to be learned about the nature and assessment of arterial street sustainability.

Gaps in the scholarly record on the sustainability of arterial streets to be filled with research undertaken in this dissertation research.

Domains, variables, and empirical testing.

Hoehner et al. (2003) concluded that more research is needed to “define the domains and the variables within the community environment that foster more walking and cycling” (p. 17). Frank and Engelke (2000) have pointed out that “few studies have attempted to rigorously determine the effect of street design” (p. 118). Ewing and Cervero (2001) note that there has been far less research on the impact on “features of the built environment” on travel than “research on land use patterns” (p. 89). The same scholars also call for “much more empirical testing and replication of results” to establish “what exactly constitutes transit friendliness or walking quality” and the relationship of both to travel choices (p. 106).

Handy, et al. (2002) cited the need for qualitative research in order “to identify the characteristics of the built environment that should be measured and to explore appropriate ways of measuring them”. As an example, they note that “data on walking behavior must be spatially matched to detailed data on the built

environment” (Handy et al., 2002, p. 72). While “high connectivity, human-scale streets, and desirable aesthetic qualities” are seen as making walking a feasibly, attractive option, the researchers conclude that there had been to date little “empirical testing of the connections between these characteristics and pedestrian behavior” (Handy, et al, 2002, p. 66).

Objective data and complexity.

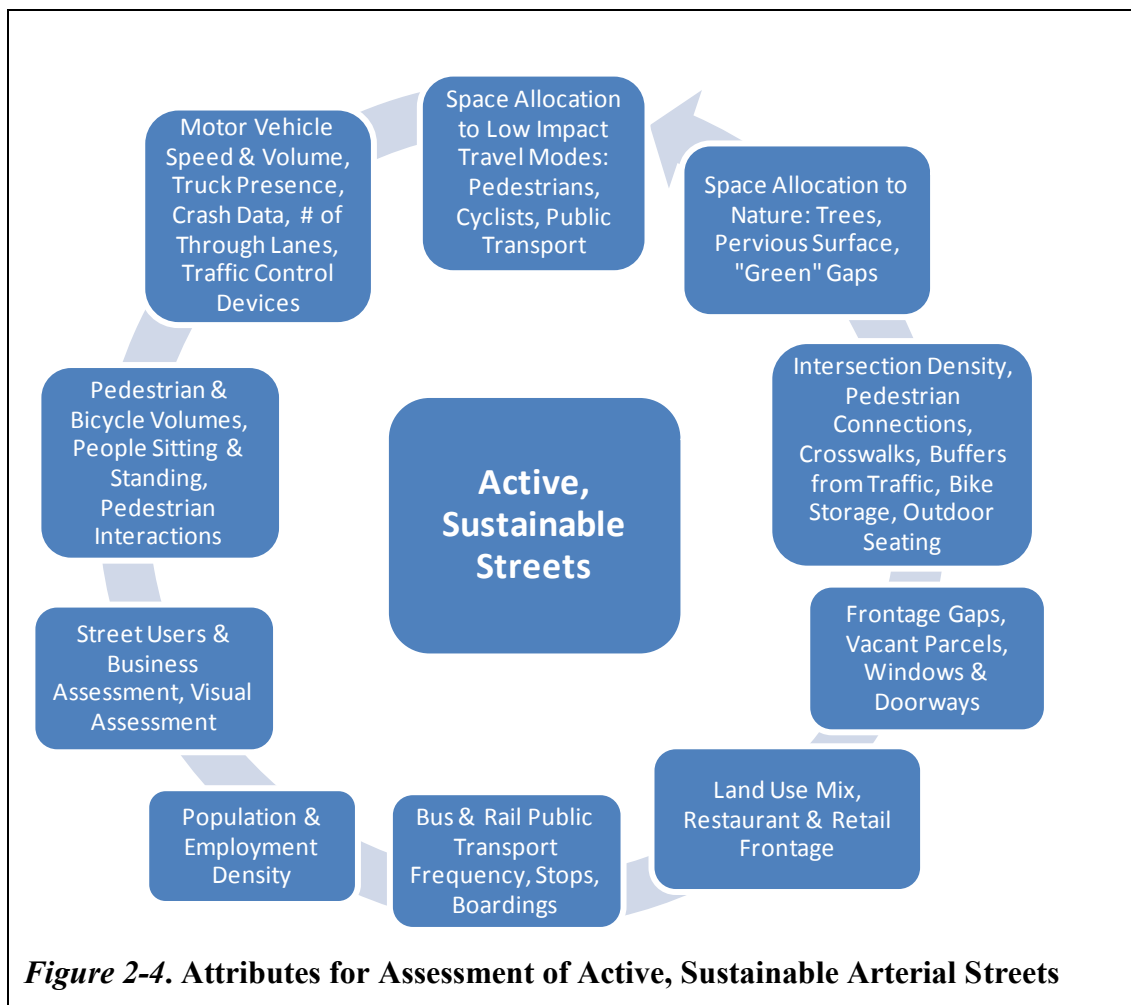
Moudon and Lee (2003) assert that “work remains to assemble objective data of environments at a grain or resolution fine enough to correspond to those sensed by walkers and bicyclists” and that “the lack of detail and accurate data” is the “single more important issue to address” regarding “environmental predictors of walking and bicycling” (p. 36). Shay et al. (2003) observe that “the literature for walkability and walking is relatively young and incomplete”, partly due to “the complex interactions between human behavior and environments with a rich variety of combinations and formulations of design and function” (p. 16). Lamont (2001) warns about “the reductionist tendency for viewing variables in isolation”, which does not capture the “synergistic qualities of pedestrian environments” (p. 32). Owen et al. (2004) call for more reliable measures of “environmental attributes” related to walking (p. 74). Moudon et al. (2006) claim that, “significant changes in research methods” into the determinants of walking are needed due to the “fine-grained measurement suggested by the threshold values” of their own research (p. S113).

Filling some of the gaps.

In summary, there has to date been no comprehensive, multi-measure evaluation of the arterial street sustainability that combines fine-grained metrics on the built environment, detailed and multimodal travel data, and multi-year crash data with survey research, focus group sessions and visual preference surveys to explore the human dimensions of sustainable arterial streets in a comparative framework. The 1:2 matched pair design used by Bosselmann et al., (1999) to study the effects that traffic volumes and boulevard street design had on street residents in Chico, California and Brooklyn, New York is a promising methodology for a comparative study of streets. The scholarly record, however, lacks such a comparative study in depth of the attributes and determinants of active, sustainable arterial streets. This dissertation research is designed to fill that gap in the literature on arterial street sustainability.

Selecting attributes for analysis.

The complexity and multi-disciplinary nature of this task was depicted in Figures 1 through 3, which summarize the disciplinary domains, geographic scales, and details of the research that must be completed in order to achieve this aim. Figure 4 below shows the key topics, issues, or variables that need to be included based on the literature review. Figure 5 presents my own assessment of the strength of the evidence in the literature on the influence on or support for these attributes sustainable arterial streets.



While these variables were selected in a largely inductive manner, their selection was based on a careful study of the scholarly literature on active, sustainable streets. My experience as a transport planner helped me to both appraise and supplement the literature. When the literature was complex or contradictory in a particular area, I drew heavily on my professional experience. The next chapter

describes how these attributes were defined, made operational, and incorporated into the analytical work of this dissertation research. These were the means by which the findings presented in Chapter 5 were produced.

CHAPTER 3

METHODOLOGY

Research Approach

This Chapter presents the design and methods for the research used to examine arterial “streets of clay”. The content includes the process for selecting of streets to study, the mixed-methods approach to the studying them, and both the basis for and detail on methods employed. As shown in Chapter 2, the study of arterial streets requires exploration of a diverse set of topics in the scholarly and practitioner literature. Similarly, a diversity of research methods is needed to conduct research about streets.

This research effort began with eight questions grouped into three broad categories: 1.) “active” streets, 2.) street design and function, and 3.) “sustainable” streets. The research design, choice of streets to study, methodology, and the selection of variables used to evaluate each street were all undertaken with these eight questions in mind. The questions by category are as follows:

“Active” streets.

1. What are “active” streets and how can “activity” on streets be measured?
2. To what extent does continuous street (building) frontage contribute to “active” streets and, if so, how can its contribution be measured?

Street design and street function.

3. To what extent does street design (geometry, partitioning of space) affect street use and, if so, how?
4. What are “complete streets” and how can “completeness” be measured?
5. To what extent does dedicated space for pedestrians, cyclists, and public transport users contribute to the amount of walking, bicycling, and public transport use along streets?
6. What are the relationships, if any, between “space for nature” and the transport and other functions of streets?
7. To what extent does a street’s aesthetic appeal affect street use, if at all?

“Sustainable” streets.

8. How can the “sustainability” of urban commercial streets be measured?

The common research problem of “breadth versus depth” in evaluation methods (Hunter and Brewer, 2003) was resolved in this study by choosing depth at the cost of breadth. Six streets were selected as case studies. An assortment of

primary and secondary data was collected on each of the case study streets, rather than a narrow band of data on a large sample of case study streets. This approach was taken to both conserve study resources (temporal and financial) and also in response to the complexity of the research questions to be addressed, which need to cover many different, quite complex and often somewhat “subjective” issues. It was necessary, therefore, to employ as wide a suite of complementary and corroborative data as possible. The implications of this decision for statistical analysis are discussed in the last section of this chapter. The implications for future research are discussed in Chapter 7.

The methodological framework for the research is one of “mixed methods” (Morse, 2003), which involve use of a combination of quantitative and qualitative analytical tools. The approach taken in this study is to compare one “Big City”⁷ and one “Small City” commercial⁸ street, each of which has been designed or re-designed to re-allocate right-of-way away from motor vehicle movement to other street purposes, with two similar Big City and two Small City commercial arterial streets, respectively, that have not been re-designed. Commercial, rather than residential streets were of interest in this research study, because these streets tend to have much higher trip-generation rates than do residential streets (Institute of Transportation Engineers, 2008)⁹, as well as being important “human places” enlivened by a variety of people and activities.

Streets may be compared on many dimensions. These include street geometry (number, type, and width of lanes; vertical and horizontal alignment), pavement condition, adjacent land uses, geographic location, traffic volumes, traffic speeds, traffic control (signals, roundabouts, signs, striping) and function within the street

⁷ “Big City” is defined for purposes of this research as a municipality with a population of more than 750,000; “Small City” is defined as a municipality with a population of less than 100,000. For the period 2006 through 2008, the two Big City municipalities in this research, San Francisco and San Jose, had average estimated populations of 798,176 and 905,180, respectively. The three Small City municipalities in this research, San Carlos, Palo Alto, and Mountain View, California, had estimated populations of 28,652, 63,370, and 73,847, respectively. U.S. Department of Commerce, Bureau of the Census. *American Community Survey* (2009). Retrieved from the Metropolitan Transportation Commission - Association of Bay Area Governments (MTC-ABAG) Library website: <http://www.bayareacensus.ca.gov/>

⁸ “Commercial streets” are defined for purposes of this research as those on which commercial uses (retail, office, restaurant, and other non-residential land uses) occupy more than 50% of street frontage.

⁹ Retail and restaurant land uses generate from 3 to 32 times more motor vehicle trips than do multifamily residential uses (ITE, 2008).

system.¹⁰ No two streets or even two segments of the same street are identical. In addition, a robust set of “before” and “after” data is difficult to obtain for streets that have been designed or re-designed to reallocate space away from motor vehicle movement in that: 1.) Commercial street re-designs of this kind are still comparatively rare, although they are increasing¹¹ and 2.) Data collection on streets, whether or not re-designed, is almost always limited to vehicular traffic volumes, traffic speeds, intersection operations, and related information pertaining to motorized traffic (Rose, 1999). Even these data are not always available. In recognition of this limited amount of readily available data, a modified matched pair methodology was used in this research project.

A matched pair comparison of one “test” (re-designed) street to one “control” (not re-designed) street was modified to a 1:2 comparison. Matched pair study designs have been used successfully in transportation research (Rephann, 1994; Bosselmann, et al., 1999; Mokhtarian, 2002). While no two streets are identical, two control streets may together share more attributes with a test street than would just one control street. The most salient attributes for purposes of this research were chosen to measure affinities between and among streets. Attributes related to street design, including street width and number of motor vehicle lanes, were omitted in the assessment of street affinities as the differences in these attributes as they relate to use of streets are subjects of the research. The attributes chosen to screen streets for degree of affinity with each other, by category, are shown on Table 1.

¹⁰ For an excellent discussion of street function, see Marshall (2005).

¹¹ Current information about “complete streets” and “livable streets” (both terms signifying multi-purpose streets) efforts in the US is available from the National Complete Streets Coalition and Context Sensitive Solutions.org. and can be retrieved from <http://www.completestreets.org/> and <http://contextsensitivesolutions.org/>

Table 3-1

Screening Attributes for Choosing Research Streets

Context	Question
Geographic	City size: larger or smaller? Downtown location: yes or no?
Significant (person) trip generator	Proximate to major league sports facility: yes or no? Proximate to public transport station: yes/no?
Traffic operations/ Transportation function	AADT < 30,000 vehicles or AADT > 30,000 vehicles < 60,000 vehicles? Motor vehicle speeds, 85 th percentile: < 30 mph (48 kph) or >30 mph (48 kph)? Street functions as a freeway extension: yes or no?

The two geographic context attributes are fundamental in placing streets in the context of urban structure. Larger cities are assumed in this research to have more complex travel patterns, including many more origins and destinations for local trips than smaller cities. As a result, these bigger places require more complex transport systems to serve these travel patterns¹². Downtowns are assumed to be places with, by definition¹³, a high degree of land use mix in close proximity, thus are areas characterized by a multiplicity of person trip destinations and short trip lengths between and among these destinations.

The two “significant (person) trip generator” attributes show which streets have to serve the high travel demand peaks¹⁴ that arise with major sporting events and passenger train or ferry arrivals and departures. The assumption is that travel demand because of these trip generators has implications for street design and modal options provided on or in proximity to a street. This is especially true of those professional sports with a large number of home field or home arena games each

¹² Information on the complexity of public transport systems in the California cities of San Francisco, San Jose, and Oakland, the three most populous San Francisco Bay Area cities, compared to smaller Bay Area cities, for service frequency and route coverage can be retrieved from the Transit.511.org web site:

http://tripplanner.transit.511.org/mtc/XSLT_TRIP_REQUEST2?language=en

Similarly, the differences in complexity of the street systems in these three larger Bay Area cities, compared to smaller Bay Area cities, can be evaluated using the geographic information tool Google Earth. One useful measure of complexity in street systems is street intersection density, measured as intersections per square mile or square kilometer (Dill, 2004).

¹³ A definition of a downtown is “the central area or commercial center of a town or city”.

Retrieved from <http://www.webster-dictionary.org/definition/Downtown>

¹⁴ For a discussion of the arrival peaks associated with major league baseball stadia, see Grava and Nangle (2007).

season.¹⁵ Public transport passenger stations generate demand on adjoining or nearby streets for pedestrians, buses, taxicabs, bicyclists, and private motor vehicles going to or leaving the station area.

The three “traffic operations/transportation function” attributes of a street show the extent of accommodation to motor vehicle travel. Since the early part of the twentieth century, streets and the street system in US cities have been in the process of adaptation to the demands of motor vehicle traffic (McShane, 1994). Indicators of accommodation to the demands of motor vehicle traffic made by or expected of a street include the following: the volume of motor vehicle traffic on a street, the speed of that traffic (during off-peak hours, if not during more crowded peak commute hours), and a given street’s place or function in a city’s or even metropolitan area’s hierarchy of street functions. Traffic engineers consider the metric “85th percentile speed”, the speed that 85% of drivers travel at or below on a given street segment, to be the maximum prudent safe speed (Fitzpatrick, Carlson, Brewer, Wooldridge, & Miaou, 2003).

These seven attributes were used to assess the degree of affinity between each of the test streets with each of the control streets. Un-weighted results show the number of shared attributes (or affinities) from 0 to 7. A second assessment was done by assigning twice the weight to the annual average daily traffic volume and 85th percentile motor vehicle speeds attributes than that given to the remaining five attributes. This weighting recognizes that the amount and speed of motor vehicle traffic have powerful impacts on conditions for travel on and across a street, especially for pedestrians and bicyclists¹⁶. This weighting yields a possible “score” of shared attributes from 0 to 9.

Selection of Street Segments

Test and control streets were identified in the research by a heuristic process that included street segments I knew in the San Francisco Bay Area to have been designed or re-designed to accommodate more uses than just motor vehicle travel.

¹⁵ Major league baseball teams, including the San Francisco Giants host 81 scheduled games and up to an additional 12 post-season playoff home games each season. Professional ice hockey teams, including the San Jose Sharks, have 41 scheduled games and up to an additional 16 post-season home games each season. In addition, major league sports stadia and arenas typically also host collegiate and high school games along with concerts and other special events during the year.

¹⁶ Reducing motor vehicle speeds and volumes to support safer and more comfortable walking and bicycling, for example, is a key objective in “traffic calming” measures. Material on traffic calming can be retrieved from the U.S. Department of Transportation, FHWA, web site: <http://www.fhwa.dot.gov/environment/sidewalk2/sidewalks209.htm>

Several transport planning colleagues with knowledge of street design projects in the Bay Area were also consulted in the process of selecting street segments for this study.¹⁷ The universe of commercial streets in the Bay Area (rather than in other regions of the country or the world) was chosen because I live and work in the Bay Area, am familiar with the Bay Area transport system and urban structure¹⁸, and have ready access to the streets themselves for primary data collection, as well as to Bay Area public agencies for secondary data collection. An additional benefit to research within a single metropolitan area is the potential to minimize the influence of any cultural, institutional, historical, or other factors that may pertain to street use but can vary between metropolitan areas.

Street segments of from .3 mile or .5 kilometer, to .6 mile or one kilometer, were chosen as a practical length along which to collect data on a variety of street physical characteristics and use variables. Street segments within this span typically serve a mix of land uses but are of a manageable size for collection of the extensive data required by the research design chosen for this study. This distance also suited the needs of a research effort with a focus on pedestrian activity, as most pedestrian trips in the US are less than one-half mile, or .8 kilometer, in distance and the median pedestrian trip distance is approximately .25 mile or .4 kilometer (Agrawal & Schimek, 2007).

Several notable potential test street segments were considered. For the larger city street segment, these included the East 14th Street re-design project¹⁹ in Oakland, California, the Octavia Boulevard project²⁰ in San Francisco, the King Street - The Embarcadero project in San Francisco (Cervero, Kang, and Shively, 2007), and the Valencia Street re-striping project (Sallaberry, 2000) in San Francisco. For the smaller city street segment, these included the Middlefield Road and Broadway Street re-design projects in downtown Redwood City, California (Congress for the

¹⁷ These included Jeffrey Tumlin, Jeremy Nelson, and Patrick Siegman of the San Francisco, CA transport planning firm Nelson/Nygaard Consulting Associates; Chris Thnay, PE, AICP of the Pleasanton, CA transport engineering firm TJKM; and Terry Bottomley of the urban design firm Bottomley Associates in Oakland, CA. All are gratefully acknowledged.

¹⁸ I have worked for thirteen years as a professional transport planner in the San Francisco Bay Area on studies, plans, and projects in six of the nine Bay Area counties, including all three of the counties in which the six street segments in my dissertation research are located.

¹⁹ A description of this project can be retrieved from the Alameda County Community Development Agency web site: <http://www.acgov.org/cda/redevelop/projects/e14street/index.htm>

²⁰ Information about Octavia Boulevard can be retrieved from SF Gate, the San Francisco Chronicle's online edition web site: <http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2007/01/03/BAG4VNBUJM1.DTL>

New Urbanism, n.d.) and the Castro Street re-design project in downtown Mountain View, California (Perry, 2006, pp. 78-80).

East 14th Street was ruled out because of the short length (approximately .11 of a mile or about .17 kilometer) of the re-designed segment. Octavia Boulevard was eliminated from consideration as land uses abutting the street are largely residential, not commercial. In addition, Octavia's boulevard design separates motor vehicle movement from pedestrian and bicycle movement, which are in turn accommodated on frontage streets flanking each side of the main thoroughfare. This design is therefore not well suited to test an important topic of this research: the effects of integration of pedestrians and bicyclists with motor vehicles in street design ("complete streets").

Valencia Street was eliminated as this street was re-striped, not re-designed with new medians, pedestrian crossings or crosswalk treatments, intersection treatments, street furniture, and so forth. Thus, it was not transformed to the same degree as either Castro Street or King Street - The Embarcadero. Middlefield Road was eliminated because the length of the transformed street segment, only .07 mile, or .11 kilometer, was deemed too short for the purposes of data collection and comparative analysis.

Broadway Street was not chosen as the re-design of both this street and Middlefield was completed less than a year before initiation of data collection for this research²¹, which was considered to be an insufficient amount of time for re-settling of traffic patterns, especially as introduction of downtown-wide paid parking was planned to begin in conjunction with the street re-designs (Zack, 2005).

This process of elimination left King Street - The Embarcadero and Castro Street, both commercial streets that were within the desired .3 to .6 mile or .5 to one kilometer reach. A .56 of a mile (.9 of a kilometer) section of King Street – The Embarcadero was chosen as the Big City test street. This segment extends from 3rd Street on King Street, where the bicycle lanes begin, and ends immediately past the light rail platforms at The Embarcadero and Brannon, the second set of light rail platforms on this segment. A .52 mile or .87 kilometer section of Castro Street was chosen as the Small City test street. This segment extends from Church Street to W.

²¹ Retrieved from the City of Redwood City E-News web page:
<http://www.redwoodcity.org/e-news/issue36.html#theatre>

Villa Street and includes most of the commercial street frontage on Castro Street, as well as Mountain View City Hall and the Mountain View Center for the Performing Arts adjacent to City Hall. Both of these street segments are proximate to commuter rail stations.

A number of control street segments were considered as a comparison to King Street - The Embarcadero and Castro Street. As discussed previously, the long list for each control pair (as well as the long list of potential test street segments) was developed heuristically based on my knowledge of the Bay Area transport system and in consultation with several Bay Area professional transport planning colleagues. The Big City list is as follows:

- Lombard Street/US Route 101 in San Francisco;
- Embarcadero West in downtown Oakland, CA;
- 19th Street/State Route 1 in San Francisco;
- The Alameda/State Route 82 in San Jose, CA; and
- Van Ness/US Route 101 in San Francisco.

All of the streets on this list are Big City commercial streets as well as commuter arteries in either San Francisco or San Jose, California. Like King Street - The Embarcadero, three of them (Lombard Street/US Route 101, 19th Avenue/State Route 1, and Van Ness/US Route 101) function as surface street extensions of freeways or limited access highways. Like King Street - The Embarcadero, one of them (The Alameda) is near a major league sports facility (HP Pavilion²², home of the San Jose Sharks professional ice hockey team). Similarly, ATT Park²³ (home field of the San Francisco Giants major league baseball team) is located at 3rd and King Street, the south end of the test section evaluated in this research study. All of the street sections considered, other than 19th Avenue/State Route 1 in San Francisco and Embarcadero West in Oakland, serve travelers destined for larger city downtowns. Two of these potential control street segments are proximate to public transport stations: a commuter rail terminal in the case of The Alameda and both passenger rail and ferry terminals in the case of Embarcadero West in Oakland.

Embarcadero West in downtown Oakland was eliminated from consideration because of the unusual circumstance of having an at-grade railroad track down the

²² HP Pavilion, completed in 1993, has a maximum seating capacity of 20,000. Retrieved from the City of San Jose web site: <http://www.sjredevelopment.org/ProjectGallery/ArenaFacts.pdf>

²³ ATT Park, completed in 2000 as Pac Bell Park, has a seating capacity of 41,502. Retrieved from the San Francisco Giants web site: <http://sanfrancisco.giants.mlb.com/sf/ballpark/sbcpark.jsp>

middle of the street that carries both intercity passenger rail²⁴ and rail freight trains. These large trains dominate the street environment and create difficult conditions for pedestrians and cyclists.

19th Avenue/State Route 1 was eliminated from consideration because the average daily vehicle traffic volumes of up to 122,000 vehicles per day on this street are much higher than the 47,000 vehicles per day on King Street - The Embarcadero.²⁵ This differential in motor vehicle traffic would have created an initial burden on 19th Avenue/State Route 1 in any comparison with King Street – The Embarcadero as regards pedestrian and bicycle activity because of the “barrier effect” high motor vehicle traffic volumes create for non-motorized travel (Russell and Hine, 1993).

Van Ness/US Route 101, which is linked to Lombard Street/US Route 101 as a surface street extension of the limited access US 101 freeway north and south of San Francisco, was ruled out for two reasons. The first was to ensure variety in the “control” segments such that each was part of a distinct facility, rather than sections of the same facility. As both Lombard Street and Van Ness Avenue are linked as designated sections of US Route 101, only one section of these two streets could be considered. Secondly, the connection between Lombard Street/US Route 101 and the freeway portion of 101 to the north does not depend on a surface street vehicular turning movement. Hence it is more direct than the connection between Van Ness/US 101 and the freeway portion of US 101 to the south.²⁶ The more direct connection from the freeway to Lombard Street is analogous to the direct connection between I-280 and King Street - The Embarcadero.

This process of elimination left Lombard Street/US Route 101 in San Francisco and The Alameda/State Route 92 in San Jose as the two control streets in the Big City subset. While Lombard Street and King Street - The Embarcadero have similar annual average daily traffic volumes (41,000 and 43,000 vehicles, respectively), annual average daily traffic on The Alameda is much lighter at 15,600

²⁴ A total of forty-six weekday intercity passenger trains use tracks in the middle of Embarcadero Street in Oakland on the Capitol Corridor, San Joaquins, and Coast Starlight routes. Retrieved from the Amtrak web site:
<http://www.amtrak.com/servlet/ContentServer?c=Page&pagename=am%2FLayout&cid=1248542957>

²⁵ Retrieved from the California Department of Transportation (Caltrans) web site:
<http://traffic-counts.dot.ca.gov/>

²⁶ Drivers exiting US Route 101 en route to Van Ness Avenue/US Route 101 must exit at Mission Street and then turn left onto Van Ness Avenue.

vehicles. Choosing The Alameda as one of the control streets was conservative, however, with respect to comparing walking and cycling conditions to the test street as motor vehicle traffic, as stated previously, can be an important barrier to non-motorized travel (Russell and Hine, 1996). The Alameda's lower traffic volumes give it an advantage compared to King Street - The Embarcadero in any research study of the effect of street design on pedestrian and bicycle activity. Maps of the two control streets and the test street for the Big City cohort are shown on Figures 1 through 3. The degree of similarity between the control and test streets was evaluated in an "Affinity Screening Matrix", displayed as Table 2.



Figure 3-1. King Street – The Embarcadero and Environs
Copyright by Google, Map Data ©2008 Tele Atlas, Image © TerreMetrics 2008.

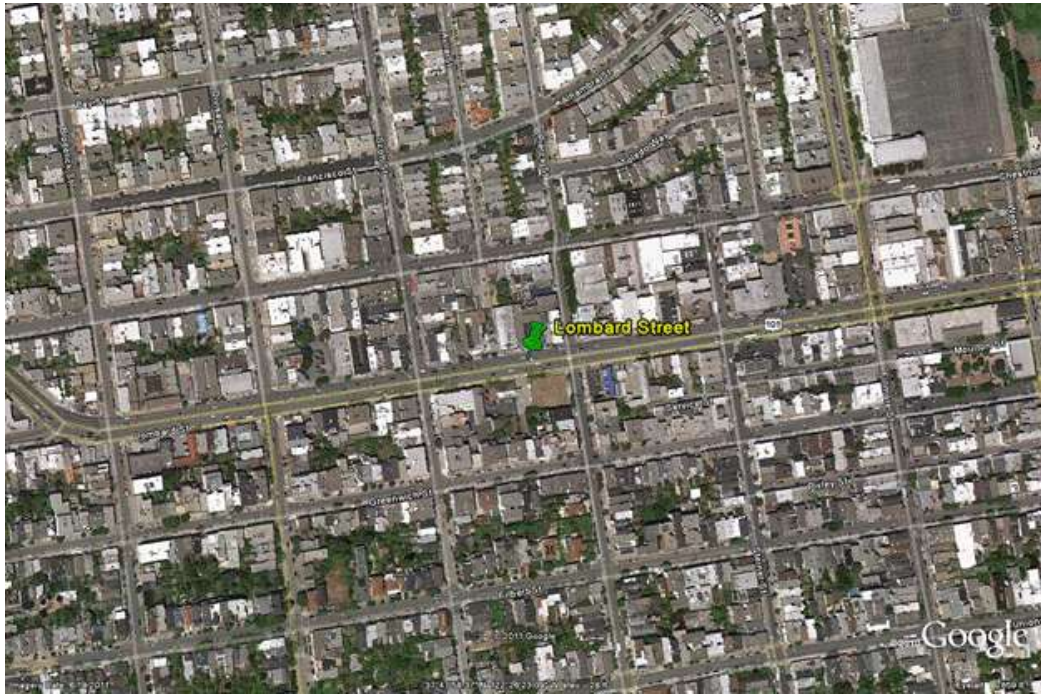


Figure 3-2. Lombard Street and Environs

Copyright by Google, Map Data ©2008 Tele Atlas, Image © TerreMetrics 2008.

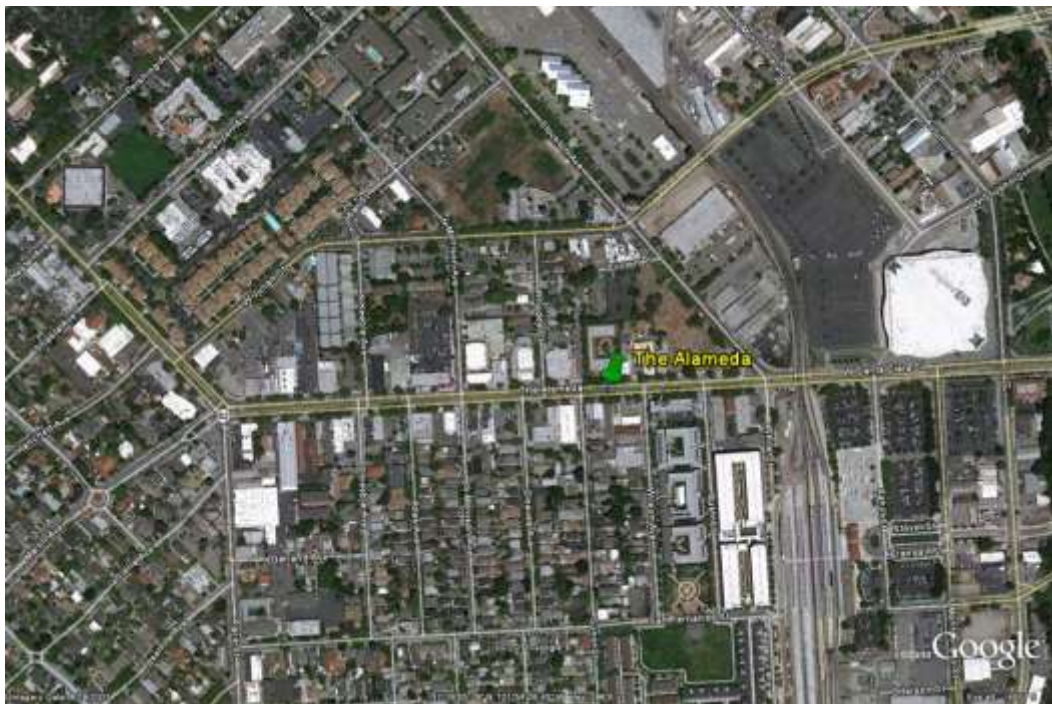


Figure 3-3. The Alameda and Environs

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Five Small City streets were considered for control segments:

- Burlingame Avenue in downtown Burlingame, CA;
- California Avenue in Palo Alto, CA;
- Main Street in downtown Redwood City, CA;
- San Carlos Avenue in downtown San Carlos, CA; and
- Santa Cruz Avenue in downtown Menlo Park, CA.

All the streets on this list are smaller city downtown commercial main streets. This includes California Avenue, which serves as the main street of Palo Alto's "second" downtown. California Avenue was formerly the prestigious Lincoln Street, residence of the prominent families of Mayfield, a town annexed in 1925 to the City of Palo Alto.²⁷ Commercial development followed annexation (Winslow, 1993). All five Small City street segments serve communities on the San Francisco Peninsula between San Francisco and San Jose and all are within .25 mile or .4 kilometer of a commuter rail station on the Caltrain passenger rail system²⁸ that serves the San Francisco Peninsula.

Burlingame Avenue, Main Street, and Santa Cruz Avenue were eliminated from consideration as the cross-section of each, one travel lane in each direction with center left turn lanes, was the same as the re-designed cross-section of Castro Street. The similarity among all these street sections neutralized comparison of the effect of street cross-section on street use, a key topic of this research project. San Carlos Avenue and California Avenue remained as the two control streets in the smaller city subset. The test street and two control streets are displayed in Figures 4 through 6. The degree of similarity between them was evaluated in the Affinity Screening Matrix.

²⁷ Retrieved from the Palo Alto Online web site:
http://www.paloaltoonline.com/news_features/centennial/1920D.php

²⁸ A list of passenger stations can be retrieved from the Caltrain web site:
<http://www.caltrain.com/stations.html>

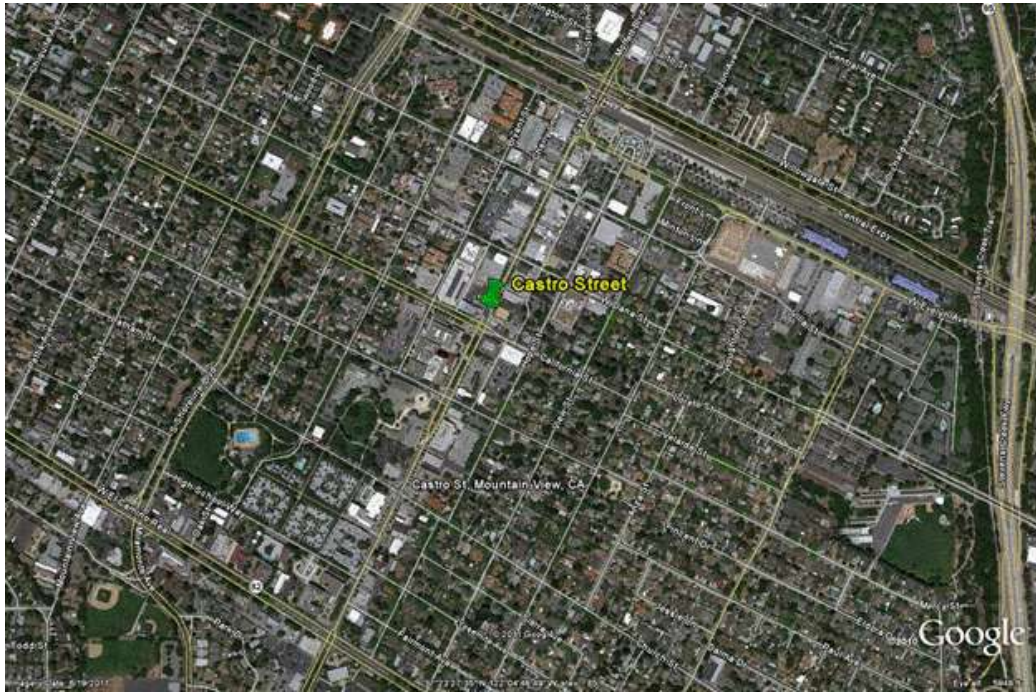


Figure 3-4. Castro Street and Environs

Copyright by Google, Map Data ©2008 Tele Atlas, Image © TerreMetrics 2008.

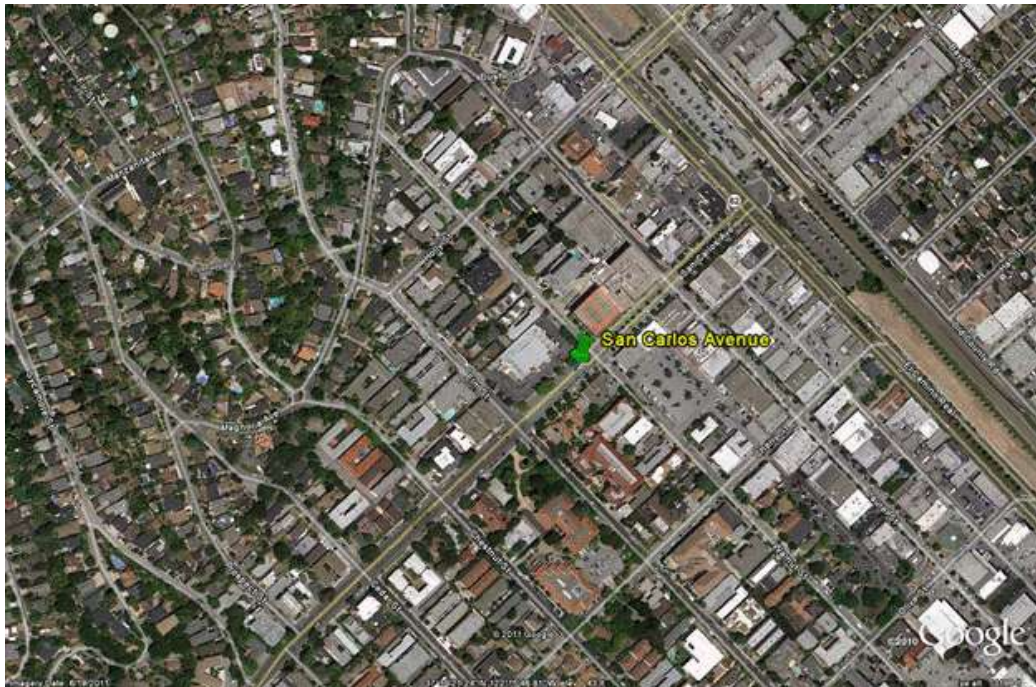


Figure 3-5. San Carlos Avenue and Environs

Copyright by Google, Map Data ©2008 Tele Atlas, Image © TerreMetrics 2008.

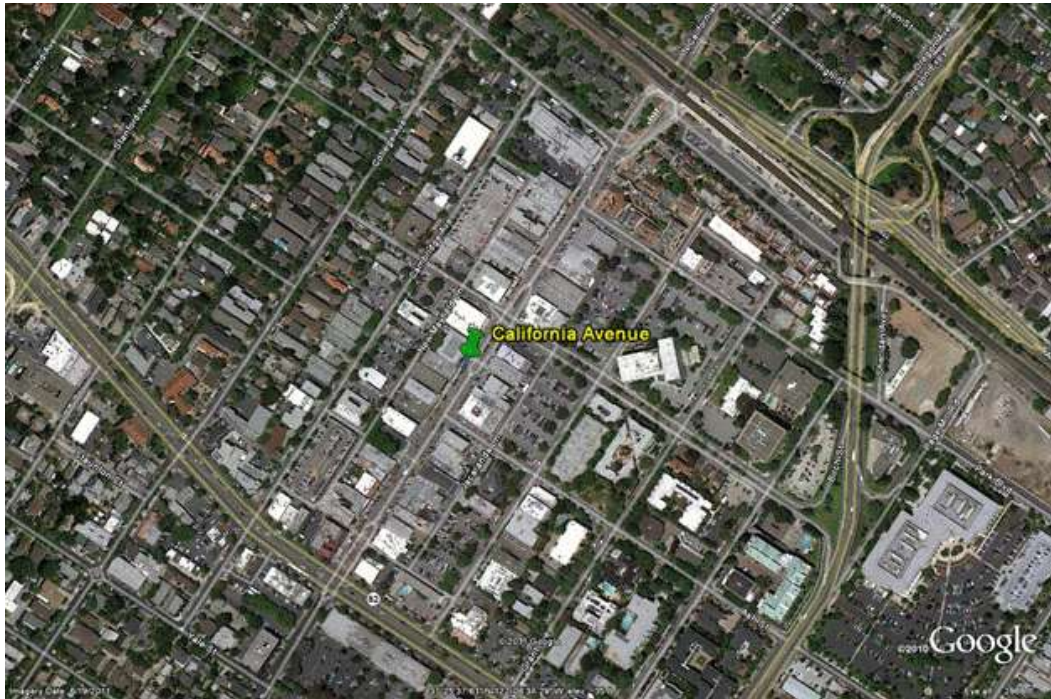


Figure 3-6. California Avenue and Environs

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The Affinity Screening Matrix was prepared to compare the two test and four control streets on the basis of the seven assessment variables described previously. The screening matrix of these assessment variables is shown as below. Each of the seven variables was weighted equally to produce an assessment rating or score of 0 to 7. The numerical results of this screening are shown as Table 3. A third matrix was developed to display scoring results when both the motor vehicle volume and motor vehicle speed variables were given a weight of 2.0 with the remaining five variables left with a weight of 1.0. The numerical scores from this weighting scheme are shown as Table 4.

Table 3-2

Affinity Screening Matrix

Metric	Street / Matches					
	LS	KE	TA	SC	CS	CA
City size	L	L	L	S	S	S
AADT > or < 30,000?	>	>	<	<	<	<
85 th percentile speed, > or < 30 mph (48 kph)?	>	>	>	>	<	<
Major sports venue?	N	Y	Y	N	N	N
Rail station proximate?	N	Y	Y	Y	Y	Y
Downtown street?	N	N	N	Y	Y	Y
Freeway extension?	Y	Y	N	N	N	N

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; SC = San Carlos Avenue; CS = Castro Street; CA = California Avenue; L = large; S = small; N = no; and Y = yes.

Table 3-3

Affinity Screening Matrix: Equal Weights (0-7 Scale)

Street	Street / # matches					
	LS	KE	TA	SC	CS	CA
LS		5	4			
KE	5		6			
TA	4	6				
SC					6	5
CS				6		7
CA				5	7	

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; SC = San Carlos Avenue; CS = Castro Street; and CA = California Avenue.

The average affinity score within the Big City subset was 5.0 out of a possible 7.0 points, or 71.4%. In contrast, the average affinity score within the Small City subset was a somewhat more robust 6.0 out of a possible 7.0 points, or 85.7%. Notably, however, the Big City control streets shared five (Lombard) or six (The Alameda) out of seven screening attributes with King Street - The Embarcadero, the larger city test street. This represents a 1:2 match of 78.6% compared to the overall 71.4% 1:1 affinity score. Moreover, the smaller city control streets shared an average of six of the seven screening attributes with Castro Street, the Small City test street. This 1:2 match of 92.9% compares to the 85.7% 1:1 overall affinity score.

After assignment of a double weight each to annual average daily traffic volume and 85th percentile speeds, the average affinity score within the larger city subset was 6.33 out of a possible 9.0 points, or 70.4%. In contrast, the average affinity score within the smaller city subset was a more robust 7.67 out of a possible 9.0 points, or 85.2%. The weighting procedure produced about the same degree of affinity within the Big City cohort, only a 1.0% decrease, and a 5.1% increase in the Small City group, compared to the case without weighting any variables. The affinity between test and control streets was 7.0 out of a possible 9.0 points, or 77.8% for the larger city subset and 8.0 out of a possible 9.0 points, or 88.9% for the smaller city subset.

Table 3-4

Affinity Screening Matrix: Double Weights (0-9 Scale)

Street	Street / # matches					
	LS	KE	TA	SC	CS	CA
LS		7	5			
KE	7		7			
TA	5	7				
SC					7	7
CS				7		9
CA				7	9	

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; SC = San Carlos Avenue; CS = Castro Street; and CA = California Avenue.

While no two streets or sections of streets are perfect analogues for each other, the affinity analysis described in the preceding paragraph highlighted important areas of similarity and difference between pairs of street sections. Although additional variables may have been included in the Affinity Screening Matrix, for example, whether State or municipally owned and operated a street (a limited practical effect across street segments²⁹) and proximity to a university (little difference across street segments³⁰), none would have added appreciably to the task

²⁹ The Alameda and Van Ness are the only State-owned street segments in the set of six chosen in this research. In practice, the City and County of San Francisco (for Van Ness) and the City of San Jose (for The Alameda) participate in many of the same activities, including landscape improvements, land use planning, and corridor planning, on these two streets as on municipally-owned streets.

³⁰ No university is within easy walking distance to any of the six street sections in this research. San Jose State University is no closer than 1.1 miles / 1.8 kilometers to The Alameda study section in San Jose; Stanford University's Library, which is approximately in the center of campus, is no closer than 2.4 miles / 3.9 kilometers to the California Avenue study section in Palo Alto; the core of the

of differentiating between and among the street sections. Lengthening the list of variables would have increased the complexity of this exercise more than adding to the illumination it was intended to provide.

I also relied on my experience as a professional urban transport planner, driver, public transport patron, bicyclist, and walker to assess the degrees of similarity and difference among these streets. I used professional and scholarly judgment in comparing the form, function, and setting of the street sections. These heuristics were also the means by which I deemed the six streets chosen as well positioned to yield answers to important questions discussed in this dissertation and in the wider literature.

I believe that King Street – The Embarcadero embodies a “complete” street, a test bed for assessing the interaction of multiple street purposes and multimodal transportation choices in an urban environment. Castro Street represents the return of a small city main street to context sensitivity. Together with the two control streets paired with each, these two test streets provide suitable laboratories for inquiry into the eight research questions on the nature and assessment of active, sustainable arterial streets posed in this dissertation.

The test and control streets were compared on an array of categories, each containing one or more variables. These variables included the following:

- allocation of space by use within the “effective”³¹ street right-of-way/ apportionment of street frontage/ bicycle and pedestrian context;
- land use abutting the street;
- streetscape attributes;
- use of the street by transportation mode;
- motor vehicle operations;
- activity by non-motorized modes;

University of California San Francisco Mission Bay campus is no closer than 1.2 miles / 1.9 kilometers to the King Street - The Embarcadero study section in San Francisco; the University of California San Francisco Laurel Heights campus is no closer than 1.4 miles / 2.3 kilometers from the Lombard Street study section. No other universities are closer to any of the six study street sections. All values are minimum driving distances retrieved from the Google Maps web site:

<http://maps.google.com/maps?hl=en&tab=wl>

³¹ Defined for the purposes of this research as the distance between the inside edge (furthest from the street) of the sidewalk or footpath on one side of the street to the inside edge on the other side. For purposes of counting café chairs, as well as pedestrians sitting, standing, and interacting, this distance was increased to up to 10 feet or 3.05 meters interior to (away from the street) the inside of each sidewalk or footpath. Field observation suggested that this was a workable boundary for measuring street activity “spilling out” from the effective right-of-way.

- visual assessment;
- street users and business assessments; and
- population and employment within a .25 mile or .4 kilometer buffer area from each side and each end of the street (for a comparison of densities this was converted to a square mile or 1.6 kilometer basis).

Data collection methods and protocols for the variables in each of these categories are described in the Data Collection section of this chapter. Selection of these variables, as well as expectations about their magnitude and direction, was based on research pertaining to the relationship of street design to street use discussed in Chapter 2, as well as my own professional judgment.

The expected direction and magnitude of relationships among variables pertaining to pedestrian activity, bicycle use, and public transport patronage are summarized in Tables 5, 6, and 7. One of the variables relating to mode choice, travel price, was not treated in this research as it did not vary appreciably across streets.³² The association of household median income in the environs of each of the streets with the activity and modal-use variables listed above was evaluated, however. Nevertheless, both travel price and household income are largely out of the purview of street corridor planning and policy.

As incomes vary by neighborhood and neighborhood residents also use nearby streets, an analysis was conducted on the relationship between median household incomes at the neighborhood level to a number of street use variables. Some caution should be taken in the interpretation of the results of this analysis, however, because of differences in size among the neighborhoods surrounding the six streets and the slight temporal mismatch between the closest available year

³² One-way adult public transport fares for public transport on the streets varied from \$1.50 (San Francisco Municipal Transportation Authority (SFMTA) and the San Mateo County Transit District (Samtrans) to \$1.75 Santa Clara Valley Transportation Authority (VTA) during the November 2007 to January 2008 field data collection period for this research, for example. Retrieved from the Samtrans, SFMTA, VTA and VTA web sites:

http://www.samtrans.com/pdf/Facts_and_Figures/ST_Facts_Figures_2007_web.pdf

<http://www.sfmta.com/cms/apress/SFMTA2007HolidaySeasonTransportationTips.htm> and

<http://www.letsqobayarea.com/transportation/vta.html>

Average Bay Area gasoline prices ranged from \$3.30 per gallon (January 2008) to \$3.41 (November 2007) during this period. Retrieved from the Metropolitan Transportation Commission web site: http://www.mtc.ca.gov/maps_and_data/datamart/stats/gasprice.htm

(2008) for median household income at this spatial scale and when (the fourth quarter of 2007) the field data were collected.³³

A third variable, travel time, was not treated explicitly but may be represented indirectly as the amount of dedicated space for either public transportation service or bicycling as well as, to a lesser degree, pedestrian travel.³⁴ Space allocated for these uses, which is part of street corridor planning, was a proxy variable for travel time.

Table 3-5

Expected Direction and Strength of Factors Influencing Pedestrian Volumes

Attribute	Expected influence	
	direction	magnitude
Traffic volume	-	xx
Traffic speed	-	xx
Tree canopy	+	x
Retail or restaurant uses	+	x/xx
Dedicated pedestrian space	+	xx
Lateral connections	+	x
Public transport service	+	xx
Through motor vehicle lanes	-	x/xx
Curb side buffer	+	x
Space for nature	+	x
Public transport stops	+	x/xx
Continuous street frontage	+	x/xx
Crosswalks	+	x
Population	+	xx
Employment	+	xx
Commercial driveways	-	x
Street frontage in vacant buildings	-	x/xx
Doorways	+	x
Windows	+	x
Public seating	+	x
[Household income]	[-]	[x/xx]

Note. + = positively correlated with pedestrian activity; - = negatively correlated with pedestrian activity; x = minor effect; xx = major effect; x/xx = could be minor or major, depending on circumstances, and [] = attribute not treated in detail in this research study.

³³ The land area of the two neighborhoods surrounding Lombard Street is about 1.1 square miles (2.8 square kilometers). In contrast, the area of the three neighborhoods around California Avenue is 2.2 square miles (5.7 square kilometers). Retrieved from these City-Data.com web sites: <http://www.city-data.com/zip/94123.html>, <http://www.city-data.com/zip/94306.html> and <http://www.city-data.com/zip/94041.html>

³⁴ I did not experience any appreciable delay because of lack of sidewalk space in walking on any of the six streets but was delayed at times as a cyclist, public transport user, and driver because of motor vehicle traffic congestion.

Table 3-6

Expected Direction and Strength of Factors Influencing Bicycle Volumes

Attribute	Expected influence	
	direction	magnitude
Traffic volume	-	xx
Traffic speed	-	xx
Dedicated bicycle space	+	xx
Lateral connections	+	x
Trucks (3 + axles)	-	x/xx
Through motor vehicle lanes	-	x/xx
Signalized crossings	-	x
Intersections	-	x
Population	+	x/xx
Employment	+	x/xx
Commercial driveways	-	x
Bike racks	+	x
[Household income]	[-]	[x/xx]

Note. + = positively correlated with bicycle use; - = negatively correlated with bicycle use; x = minor effect; xx = major effect; x/xx = could be minor or major, depending on circumstances, and [] = attribute not treated in detail in this research study.

Table 3-7

Expected Direction and Strength of Factors Influencing Public Transport Volumes

Attribute	Expected influence	
	direction	magnitude
Dedicated public transport space	+	xx
Public transport service	+	xx
Population	+	xx
Employment	+	xx
Retail or restaurant uses	-	x/xx
[Household income]	[-]	[x/xx]

Note. + = positively correlated with public transport use; - = negatively correlated with public transport use; x = minor effect; xx = major effect; x/xx = could be minor or major, depending on circumstances, and [] = attribute not treated in detail in this research study.

Data Collection

Primary data for this research effort were collected by a combination of physical inventories of street rights-of-way and both surveys and focus group sessions with street users and business people. Secondary data were obtained from local, regional, and state public agencies with responsibility for planning and management activities pertaining to each street.

Allocation of street space, apportionment of street frontage, and bicycle and pedestrian context.

A comprehensive field inventory was conducted on all six street segments in this research study. The dates of the field inventory on each street were as follows:

- The Alameda – 13 November 2007;
- San Carlos Avenue - 17 November 2007;
- Castro Street – 18 November 2007;
- Lombard Street – 5 December 2007;
- California Avenue – 8 December 2007; and
- King Street–The Embarcadero – 8 January 2008.

Data were collected on many physical attributes of each of these six streets. Except where noted, data collected was within what was defined for the purposes of this research as the “effective right-of-way”, the space between the inside (away from the street) of the sidewalk or footpath³⁵ on one side to the inside of the sidewalk or footpath on the other side of each street. This information was used in analyses that produced the research findings presented in Chapter 5. These data, annotated as needed, are explained in the list below.

Width, length and number of lanes dedicated to motor vehicle movement and parking.

Description: The total amount of space dedicated to motor vehicle movement and parking was converted to a percentage of effective right-of-way for analysis purposes.

Width and length of lanes dedicated to bicycle movement.

Description: All bicycle lanes were considered dedicated to bicycle use even if joggers and people on electric and manual scooters, skateboards, Segways, rollerblades, and roller skates also at times used this space. The total amount of space dedicated to bicycle movement was converted to a percentage of effective right-of-way for analysis purposes.

Width and length of sidewalks; this included street crosswalk sections protected on one or both sides by a median of a minimum of 6 feet or 1.8 meters width.

³⁵

The American term “sidewalk” will be used in the rest of this Chapter.

Description: All sidewalks were considered to be dedicated to pedestrian use even if they were also used at times by bicycles, electric and manual scooters, skateboards, Segways, rollerblades, and roller skates. The total amount of space dedicated to pedestrian movement was converted to a percentage of effective right-of-way.

Width and length of designated public transport ways and bus stop dwell spaces.

Description: All rail public transport platform space and any buffer area between rail tracks and pedestrian waiting areas were considered to be dedicated to public transport use. The area dedicated to public transport use was converted to a percentage of effective right-of-way for analysis purposes. It should be noted that there were no dedicated bus lanes or busways on any of the six study streets.

Number of designated public transport stops.

Description: Rail passenger transport platforms serving both directions of travel were counted as two stops. As no bus stops on the study streets served both directions of travel, stops on each side of the street were counted individually. These data were normalized per mile and per kilometer for analysis purposes.

Number of bicycle storage racks.

Description: This included only those devices designed for bicycle storage and excluded devices such as street sign posts that can serve as bicycle storage when a bicycle is secured to it by a bicycle lock. These data were normalized per mile and per kilometer.

Area of permeable surface.

Description: This includes soil, grass, gravel, and other surfaces that are permeable with respect to drainage. Drainage grates above the soil around street trees were considered permeable for purposes of this research. The total amount of permeable space was converted to percentage of effective right-of-way for analysis purposes.

Area of tree canopy.

Description: This was approximated for purposes of this research by use of the simplifying assumption that each tree canopy was circular and could be calculated by applying the formula for the area of a circle, πr^2 . The radius for each tree was approximated as half the average diameter, measured from the outer edge of

tree branch line to the middle of each tree trunk. The total amount of tree canopy space was converted to a percentage of effective right-of-way.

Length of street frontage gaps.

Description: This included all street frontages without buildings within 10 feet of the inside of the sidewalk on each side of the street, excluding cross-streets and cross-street sidewalks. The total length of street frontage gaps on each street was normalized per mile and per kilometer for analysis purposes.

Length of street frontage “green” gaps.

Description: This included all publicly accessible parkland, lawn, or other landscaped or natural space within 10 feet of the inside of the sidewalk on each side of the street, whether in public or private ownership. The total length of “green gaps” on each street was normalized per mile and per kilometer.

Length of vacant building street frontage.

Description: This included all street-level building space on parcels abutting the effective right-of-way appearing in field observation to be unoccupied. Only uses with entrances on a research study street section were included in these data. This information was normalized per mile and per kilometer for analysis purposes.

Length of street frontage in restaurant and retail uses.

Description: This included all uses on parcels abutting the street-level right-of-way and defined as restaurant or retail in the *Trip Generation Handbook, 8th Edition* (ITE, 2008). These two land uses have comparatively high vehicle trip-generation rates³⁶ associated with them and for purposes of this research are also assumed to have comparatively high person trip-generation rates. Only uses with entrances on a research study street section were included in collecting these data. Auto-related retail, including auto sales showrooms, auto parts stores, and auto repair shops, were excluded. The data on amount of restaurant and retail frontage were normalized per mile. Although data on retail and restaurant square feet/meters for each street segment were unavailable, field observation and my personal knowledge of each of the street segments under study suggested that all or virtually all retail and

³⁶ Studies of vehicle trip generation by restaurants reveal an average daily trip rate of from 90 to 127 per 1,000 square feet, depending on type of establishment. The average daily vehicle trip rate for retail stores ranges from 30 to 102 per 1,000 square feet, depending on type of store. In contrast, the average daily trip rate for general office use is only 11 per 1,000 square feet and that from multifamily housing is only from 4 to 7 per unit, depending on type of unit (ITE, 2008).

restaurant space on each of the six street segments was located on the street level, not on upper floors.

Length of at (street) grade pedestrian buffer.

Description: This included car parking spaces (on all six street segments) and former car parking space converted to café space (on Castro Street), essentially everything level with street grade (below curb³⁷) that both separates and buffers pedestrians from moving motor vehicle traffic. These data were normalized per mile and per kilometer.

Number of pedestrian lateral connections.

Description: These “lateral connections” comprise sidewalks, outdoor passageways (sometimes called by the Spanish word, “*paseos*”, in California), or other space dedicated to travel by pedestrians from a research street section to parallel streets and other locations (e.g. waterfront piers on King Street –The Embarcadero) on either side. This variable is used to measure “permeability” (Punter and Carmona, 1997) of a street for pedestrian movement³⁸. These data were normalized per mile and per kilometer.

Number of striped, marked, or otherwise delineated pedestrian crosswalks along or across the street.

Description: While crossing pedestrians have right-of-way at all stop and signal controlled street intersections in California (California Department of Motor Vehicles, 2007), crossing locations specifically delineated for pedestrian crossing were taken as indicators of intent to accommodate pedestrians crossing the street³⁹. These data were normalized per mile and per kilometer.

Number of outdoor café chairs.

Description: Only chairs on the sidewalks or within ten feet interior to the inside of the sidewalks on each side of a street were counted. Café chairs separated by an enclosed wall or fence from the adjoining sidewalk, or placed on a deck or balcony above the sidewalk, were not counted. These lateral or vertical barriers minimize the integration of these types of café seating arrangements into the street

³⁷ The American usage “curb” is used in this chapter instead of the British and Australian “kerb”.

³⁸ Land Transport New Zealand (2009) has provided this concise definition of “permeability” from a pedestrian standpoint: “The extent to which an accessible environment is provided for pedestrians, free of obstruction and severance” (p. 4-3).

³⁹ The findings on effectiveness of marking crosswalks are mixed, however (Jones, 2000; Zeeger, 2004; and Fitzpatrick, et al., 2006).

right-of-way. While actual use may vary widely with time of day, day of week, weather, and restaurant success, among other factors, placing café chairs represents a market-based indicator and expectation of their use. These data were normalized per mile and per kilometer for analysis purposes.

Number of outdoor public benches and seats.

Description: Only public benches and other seats, either on the sidewalks or within ten feet interior to the inside of the sidewalks on each side of the street, were counted. Seating at public transportation stops was differentiated from other benches and seats made available for general public use. These data were normalized per mile and per kilometer.

Subjective rating of amount of informal public seating.

Description: Ledges, low walls, and similar informal places to sit, described by the urban designer Jan Gehl (2006) as “secondary seating”, provide important alternatives to the formal seating offered by café chairs and public benches. I assigned ratings on a broad, subjective “high”, “medium”, and “low” scale, based upon my use of and familiarity with each street. A partial appraisal of the reliability of these ratings can be made through use of Google Maps’ “Street View”⁴⁰ function (a pedestrian-eye look along a street) for five of the six street segments (the San Carlos Avenue study segment is not available on this function).

Doorways in use.

Description: The doorways for all non-vacant buildings within the effective street right-of-way were counted along each of the six street segments. As pedestrian trip origins and destinations, doors are an indicator of the potential for street activity. These data were normalized per mile and per kilometer for analysis purposes.

‘Active’ and/or “transparent” window space in use.

Description: Windows provide “eyes on the street” as well as create interest for passing pedestrians (Jacobs, 1961). To serve these purposes, windows must be transparent so pedestrians can see and be seen and/or contain displays⁴¹ attracting pedestrian attention. Linear feet/meters of “active” and/or “transparent” windows at

⁴⁰ More information about this function can be retrieved from the Google Maps web site: <http://www.google.com/help/maps/streetview/>

⁴¹ For vivid illustrations of the celebrated Holiday window displays in New York City, for example, see http://www.nyctourist.com/xmas_deptstores.htm

pedestrian-eye level were counted along each of the six study street segments. These data were normalized per mile and per kilometer.

Total length of street section under study.

Description: This was derived through use of the measuring tool in Google Earth and cross-checked in the field by distance wheel for accuracy.

Number of commercial driveways.

Description: Commercial driveways connect streets to retail shops and stores, restaurants, offices, multi-family residential complexes, community centers, schools, factories, and other land uses generating comparatively high traffic and parking demand⁴². The total number of driveways was summed for each of the six study street segments. Driveways connected to single-family residential uses were excluded. These data were normalized per mile and per kilometer.

Number of traffic signals.

Description: Each intersection or mid-block crossing controlled by a traffic signal was counted. These data were normalized per mile and per kilometer basis for analysis purposes.

Intersection density.

Description: This metric comprises the total number of street connections (“legs”) to all of the intersections within a .25 mile/.4 kilometer buffer area on each side and at each end of the six street segments. A four-way intersection was counted as having four and a three-way as having three legs, for example.

It should be noted that, as discussed in Chapter 2, length of building canopy, awnings, or other overhead cover for pedestrians walking along the sidewalk of the study street segments has been hypothesized as a factor favorable to walkers. These data were not collected in this research, however, as there was minimal overhead cover of sufficient width from buildings to shelter pedestrians on any of the study streets. Hence, these streets could not be differentiated on this basis.

Use of street by transportation modes.

A combination of primary and secondary data on street use by transportation mode was gathered on all six street segments in this research study. While data on use of the streets by transportation mode was collected through sampling procedures, thus subject to the variability inherent in sampling, it is important to note that there is comparative stability in non-holiday weekday travel data (Wright, 1997) that reduces

⁴² See ITE (2010) for extensive detail on observed parking demand for a variety of land uses.

the risks of sampling error. All primary data on street use for this study were collected during non-Holiday weekdays. These data were used in analyses that produced the research findings presented in Chapter 5.

I was joined in primary data collection by several students in urban planning and environmental studies remunerated for their participation in the research effort, some friends, and both my spouse and son. As pointed out above, all data were collected on weekdays during non-Holiday weeks.⁴³ To obtain primary data on transportation use by street mode, data collection stations staffed by one or two surveyors were designated on each street at approximately equal distances apart. Equal sampling time intervals were set for each station. Surveyors moved from one station to another after the prescribed sampling time interval had elapsed. I gave the surveyors verbal instructions and data collection materials (forms, pencils, and clipboards), then deployed them a for brief practice period so that they could become familiar with the data collection procedure and environment. Formal data collection began as soon as these preparatory steps were completed.

On streets with too much traffic for accurate data collection in both directions, for example in surveying for vehicle classification, care was taken to balance sampling time in each direction. Vehicle type and occupancy were recorded together, for example a “2” marked in a recording sheet box labeled “autos and light trucks”, represented a vehicle in this category occupied by two people. I am confident, based on my extensive field experience in these types of traffic studies, that more than 90% of all traffic passing the counting stations was properly recorded with no systematic under- or over-count in vehicle classification or occupancy.

Motor vehicle traffic.

Description: Secondary data on annual average daily traffic (AADT) were obtained from public agencies with the responsibility of managing each street segment in the research study. The traffic volume counts are for 2007 or the closest available year to 2007, the year in which the primary data collection for this research study took place. The daily traffic volume counts by year and by street were as

⁴³ Federal Holidays in 2007 during which some employers and school were closed in the United States were as follows: New Year’s Day (1 January), Martin Luther King’s Birthday (15 January), Washington’s Birthday (19 February), Memorial Day (28 May), Independence Day (4 July), Labor Day (3 September), Columbus Day (8 October), Veteran’s Day (12 November), Thanksgiving Day (22 November), and Christmas Day (25 December). Retrieved from the U.S. Postal Service web site: <http://www.usps.com/communications/newsroom/calendar/federalholidays.htm>

follows: Lombard Street⁴⁴ (2007), The Alameda⁴⁴ (2007), King Street - The Embarcadero⁴⁵ (2007), San Carlos Avenue⁴⁶ (2007), Castro Street⁴⁷ (2007), and California Avenue⁴⁸ (1999).

All the following data were derived from a vehicle classification study (sample survey) undertaken as part of this research project. Detailed information on primary data collection for use of street by transportation mode is shown in Tables 8 and 9. All sampling took place on non-Holiday weekdays. No traffic or public safety (police or fire) incidents, special events affecting traffic, or inclement weather took place during the sampling.

- % share of automobiles and light trucks;
- % share of two-axle commercial trucks;
- % share of vehicles with three or more axles (includes tractor trailer trucks and two-axle vehicles towing trailers);
- % share of motorcycles and motor scooters;
- % share of buses (includes regular route, paratransit, charter, and school buses);
- % share of taxicabs and commercial limousines;
- % share of bicycles;
- % share of non-motorized street modes (includes bicycles, skateboards, rollerblades, non-motorized scooters, and roller skates on street); and
- vehicle occupancy for cars/light trucks.

⁴⁴ Caltrans.

⁴⁵ SFMTA.

⁴⁶ The San Carlos Avenue AADT estimate for San Carlos Avenue in downtown San Carlos was provided to me by Parvis Mokhtari, Director of the City of San Carlos Department of Public Works.

⁴⁷ The Castro Street AADT estimate for Castro Street in downtown Mountain View is taken from the mid-point of the range of from 11,000 to 20,000 vehicles per day provided to me by the City Traffic Engineer, Mike Vroman.

⁴⁸ The AADT estimate for the California Avenue business District area was provided to me by Ruchika Aggarwal, Engineering Technician, City of Palo Alto Department of Planning and Community Environment. These were the most current daily traffic volume data for this section of California Avenue. In my experience as Palo Alto Chief Transportation Official (1999-2005) and as a patron of California Avenue restaurants and shops for the entire period between 1999 and 2007, the volume and speed of motor vehicle traffic on the street remained relatively stable from 1999 to 2007.

Table 3-8

Big City Streets Vehicle Classification Data Collection Parameters

Detail	Street		
	LS	KE	TA
Date	10.23.07	10.11.07	11.06.07
Data collection stations	8	9	6
Observation intervals	12 min	10 min	15 min
	10 min		15 min
Sampling initiated	08:17	07:51	08:01
	14:52		14:09
Weather	Partly cloudy	Partly cloudy	Cloudy
	Partly cloudy		Cloudy
Temperature	58°F (14°C)	52°F (11°C)	49°-50°F (9°-10°C)
	75°F (24°C)		51°F (11°C)
Road surface condition	Dry	Dry	Dry
Sample size (# vehicles)	3,293	2,199	1,627

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; and min = minutes. Sample size includes all street modes of travel, including cars, trucks, vans, motorcycles, bicycles, and other non-motorized modes (e.g. rollerblades, scooters, skateboards, etc.) other than pedestrians.

Table 3-9

Small City Streets Vehicle Classification Data Collection Parameters

Detail	Street		
	SC	CS	CA
Date	09.28.07	09.14.07	11.05.07
			09.26.08
Data collection stations	9	5	3
Observation intervals	10 min	10 min	10 min
			15 min
Sampling initiated	08:05	07:45	07:54
	16:03	16:07	13:57
Weather	Partly cloudy	Clear	Clear
	Partly cloudy	Clear	Clear
Temperature	52°F (11°C)	41°F (5°C)	55°F (13°C)
	60°F (16°C)	72°F (22°C)	54°F (12°C)
Road surface condition	Dry	Dry	Dry
Sample size (# vehicles)	2,847	3,055	1,212

Note. CA = California Avenue; CS = Castro Street; SC = San Carlos Avenue; and min = minutes. Sample size includes all street modes of travel, including cars, trucks, vans, motorcycles, bicycles, and other non-motorized modes (e.g. rollerblades, scooters, skateboards, etc.) other than pedestrians.

Public transport demand and supply.*Average daily public transport boardings on street.*

Description: These secondary data were collected from the public transport operators serving each one of the six research study streets and environs. This

information is of interest since, as discussed in Chapter 2, public transport patronage on a street is hypothesized to be one of the independent variables explaining pedestrian activity, as well as being a dependent variable influenced by street design, land use, population, employment, and other independent variables treated in this study. The data set includes boardings only, as alightings data were not available for all streets. As daily boardings and alightings are typically closely matched on any given street, boardings data were considered to be a sufficient indicator of comparative public transportation patronage across the six streets in this research⁴⁹.

These data include average weekday service frequency for the light rail service (N and T lines) along King Street – The Embarcadero, the only rail passenger service with passenger stops along one of the street segments. It should be noted that all public transport service frequency information provided in the tables below is based on published, rather than observed data. Actual service frequency tends to be somewhat less than scheduled due to vehicle breakdowns, traffic congestion and incidents, driver absences, and other circumstances⁵⁰. Detailed information on the coverage of secondary data collection for public transport boardings at all stops on each of the six street segments is shown in Tables 10 and 11.

⁴⁹ As an example of the closeness of this match, 50.5% of the annual 447,780 light rail patrons at the downtown Mountain View train station were boarding trains and 49.5% were alighting from trains. Year 2007 data were provided by Ms. Suzanne Walaszek of, VTA staff.

⁵⁰ SFMTA, for example, reported that actual bus and light rail runs were 4.2% below scheduled runs system-wide for the second quarter of 2007. Retrieved from the SFMTA web site: <http://www.sfmta.com/cms/mtep/documents/01.29.08%20SFMTA%20Board%20Report.pdf>

Table 3-10

Big City Streets On-Street Public Transport Usage Data Collection Parameters

Detail	Street		
	LS	KE	TA
Operator	SFMTA	SFMTA	VTA
Route (s)	28,43	N,T	22,522,62,63
Data collection period	10.06 – 6.07	10.06 - 06.07	07.07 - 06.08
		09.07 – 12.07	
Operator	GGBHT		
Route (s)	54,70,72, 73,76,80,93		
Data collection period	2007		

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; GGBHT = Golden Gate Bridge, Highway, and Transportation District; SFMTA = San Francisco Municipal Transportation Agency; and VTA = Santa Clara Valley Transportation Authority; and N, T = SFMTA light rail lines.

Table 3-11

Small City Streets On-Street Public Transport Usage Data Collection Parameters

Detail	Street		
	SC	CS	CA
Operator	Samtrans	VTA	VTA
Route (s)	295	51,52,34,35	89
Data collection period	05.15.08 - 05.22.08	07.07 - 06.08	07.07 - 06.08
Operator			Stanford
Route (s)			C
Data collection period			2007

Note. SC = San Carlos Avenue CS = Castro Street; CA = California Avenue; Samtrans = San Mateo County Transit District; and Stanford = Stanford University Marguerite shuttle bus service.

Average daily light rail transit service frequency adjacent.

Description: These data represent average weekday service frequency for rail public transport stops within .25 mile or .4 kilometer of the street segments, adjacent to but not on these streets. Table 12 summarizes data collection detail on this data set.

Table 3-12

Adjacent Light Rail Service Data Collection Parameters

Detail	Street					
	LS	KE	TA	SC	CS	CA
Operator			VTA		VTA	
Route (s)			902		902	
Data collection period			07.07 - 06.08		07.07 - 06.08	

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; SC = San Carlos Avenue CS = Castro Street; CA = California Avenue; and VTA = Santa Clara Valley Transportation Authority.

Average daily bus transit service frequency adjacent.

Description: This data set comprises average weekday service frequency for bus public transport within .25 mile or .4 kilometer of the street segments, adjacent to but not on these streets. Tables 13 and 14 display the detail on collecting these data.

Table 3-13

Big City Streets Adjacent Bus Service Data Collection Parameters

Detail	Street		
	LS	KE	TA
Operator	SFMTA	SFMTA	VTA
Route (s)	30, 30X, 43, 22, 41, 45	10, 30, 45, 47, 80-X, 81X, 82X	64, 65, 68 168, 180, 181, DASH
Data collection period	10.06 – 06.07	09.07 - 12.07	07.07 - 06.08
Operator		AMTRAK (bus service)	AMTRAK (bus service)
Route(s)		CC, SJ	Hwy 17X, ACE Shuttle
Data collection period			
Operator		MST	DB
Route(s)		55	DB1, DB2
Data collection period		09.07 – 12.07	09.07 – 12.07

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; SFMTA = San Francisco Municipal Transportation Agency; VTA = Santa Clara Valley Transportation Authority; AMTRAK = the National Railroad Passenger Corporation; and MST = Monterrey – Salinas Transit.

Table 3-14

Small City Streets On-Street Public Transport Usage Data Collection Parameters

Detail	Street		
	SC	CS	CA
Operator	Samtrans	VTA	VTA
Route (s)	295, 260	22,522	89, 22,522
Data collection period	397, KX, PX		182,104, KX
	09.07 – 12.07	07.07 -06.08	07.07 – 06.08
Operator			Stanford
Route (s)			SE, VA
Data collection period	09-07 – 12.07	09-07 – 12.07	09-07 – 12.07
Operator			DB
Route(s)			DB 1, DB2
Data Collection period			09.07 – 12.07

Note. SC = San Carlos Avenue CS = Castro Street; CA = California Avenue; Samtrans = San Mateo County Transit District; Stanford = Stanford University Marguerite shuttle bus service; and DB = Dumbarton Express.

Average adjacent daily commuter rail transit frequency

Description: These data include average weekday service frequency for commuter rail transport within .25 mile or .4 kilometer of the street segments. Tables 15 and 16 summarize data collection detail on this data set.

Table 3-15

Big City Streets Adjacent Commuter Rail Service Data Collection Parameters

Detail	Street		
	LS	KE	TA
Operator		Caltrain	Caltrain
Route (s)		SF - SJ	SF – SJ
		SF – Gilroy	SF - Gilroy
Data collection period		09.07 - 12.07	09.07 - 12.07

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; Caltrain = Peninsula Corridor Joint Powers Board commuter rail service; SF = San Francisco; and SJ = San Jose.

Table 3-16

Small City Streets Adjacent Commuter Rail Service Data Collection Parameters

Detail	Street		
	SC	CS	CA
Operator		Caltrain	Caltrain
Route (s)		SF - SJ	SF – SJ
		SF – Gilroy	SF - Gilroy
Data collection period		09.07 -	09.07 -
		12.07	12.07

Note. SC = San Carlos Avenue CS = Castro Street; CA = California Avenue; Caltrain = Peninsula Corridor Joint Powers Board commuter rail service; SF = San Francisco; and SJ = San Jose.

Motor vehicle traffic operations.

Description: These data comprise primary (vehicle speeds, number of motor vehicle travel lanes) and secondary (speed limit) data on motor vehicle use, regulation, and facility provision. Motor vehicle spot speed data were collected by radar gun sampling during off-peak, non-Holiday weekday times for each street, which ensured that motor vehicle speeds were not materially affected by traffic congestion. No traffic or public safety (police or fire) incidents, special events, or inclement weather took place during the sampling. Sample sizes were all above 100, the recommended minimum for such traffic studies (Homburger, 1996). One data collection station was established just before and one approximately in the middle of each of the six street segments in this research study. Survey locations were all far enough from intersections so that braking and accelerating effects on vehicle speeds were minimized. All spot speed data were collected by radar gun by me sitting in a parked car located in a parking space along each street. Care was taken to use the radar gun as unobtrusively as possible so as to not affect driver behavior. Solo and lead vehicles were singled out in doing the survey. This minimized the slower speed bias inherent in collecting spot vehicle speed data on cars following the lead vehicle in a platoon. An approximately equal number of vehicles traveling in each direction were sampled. The resulting spot speed data were partitioned into 85th, 50th, 15th, and 95th percentiles, as well as a low-high range. Tables 17 and 18 show parameters for motor vehicle speed primary data collection.

Table 3-17

Big City Streets Traffic Operations Data Collection Parameters

Detail	Street		
	LS	KE	TA
Date	01.17.08	01.17.08	11.16.07
Sampling initiated	10:52	09:50	08:15
	11:13	10:12	09:50
Weather	Clear	Clear	Cloudy
	Clear	Clear	Clear
Road surface condition	Dry	Dry	Dry
Sample size (# vehicles)	110	112	111
	103	112	112

Note. LS = Lombard Street; KE = King Street – The Embarcadero; and TA = The Alameda.

Table 3-18

Small City Streets Traffic Operations Data Collection Parameters

Detail	Street		
	SC	CS	CA
Date	11.02.07	11.02.07	11.02.07
	12.13.07	12.21.07	12.13.07
Sampling initiated	15:00	8:25	9:21
	09:22	07:30	10:12
Weather	Clear	Clear	Clear
	Partly cloudy	Clear	Clear
Road surface condition	Dry	Dry	Dry
Sample size (# vehicles)	108	115	108
	112	105	103

Note. SC = San Carlos Avenue CS = Castro Street; and CA = California Avenue. Off-peak motor vehicle traffic conditions on Castro Street, a restaurant and retail but not a commuter street, were observed to be during morning hours before 9 a.m.

Non-motorized modes.

Description: These data were collected on weekdays during non-Holiday weeks at mid-day and late afternoon/early evening time intervals to capture walking and cycling attendant to the lunch hour, after work commuting, and evening dining. No traffic or public safety (police or fire) incidents, special events, or inclement weather took place during the sampling. Exact sampling start times and sampling intervals were dependent upon survey crew availability. Survey team members rotated location after each sampling interval. Typically, one member of the survey team started a rotation at the opposite end of a study street segment from a second member of the survey team. Care was taken to avoid overlapping survey intervals by

the pair of surveyors and also to avoid time bias in the sampling through the scheduling of sampling times at each sampling station.⁵¹

Pedestrian and bicycle movements.

Description: These data comprise counts of pedestrians crossing or moving alongside and bicyclists traveling on or across a street segment. Pedestrians were observed at intersection and mid-block crossing locations. Each pedestrian movement across (including more than one street crossing by an individual) was counted as a crossing movement. Each pedestrian movement alongside a street without changing direction of travel was counted as a pedestrian movement along the street (see Figures 7 and 8). Each bicycle movement along a street segment or either on, to, or from a cross street was counted as a bicycle movement along the street (see Figure 9). Each bicycle movement crossing the street only and not traveling along the street segment was counted as a bicycle crossing movement (see Figure 9). Surveyors were stationed near crosswalks at intersections and mid-block locations. All data for each of the six street segments studied were normalized on a per observer hour basis. Children in baby carriages and pouches were counted as pedestrians and all pedestrian crossings within 20 feet or 6 meters of a delineated pedestrian crossing were counted. Pedestrians who could be observed crossing beyond this limit were noted as “jaywalkers”, but also counted. Tables 19 and 20 summarize data collection detail for bicycle and pedestrian movement. These data were normalized on a per observer hour basis for comparative analysis purposes. There were no weather conditions or special circumstances (e.g. special events, holidays, crashes, travel lane or sidewalk closures) that affected street and sidewalk use on observation days. There were no meaningful differences in street topography. All streets are easily walked or biked without undue effort due to change in street grade. There were only minor differences in observational time frame for nonmotorized travel across the six streets. All data collection took place on non-holiday weekdays. In my own professional experience in traffic studies, there is very little difference in traffic volumes on streets across ordinary weekdays, absent special events, crashes, inclement weather conditions, or other special circumstances. From these considerations I conclude that there were no consequential effects on the

⁵¹ A list of sampling times by data set collected at each station and sampling interval are available at the URDMS Curtin University research data repository.

internal validity of sampling results. In my view, the same caveats apply to travel mode shares or splits as well as street user assessments.

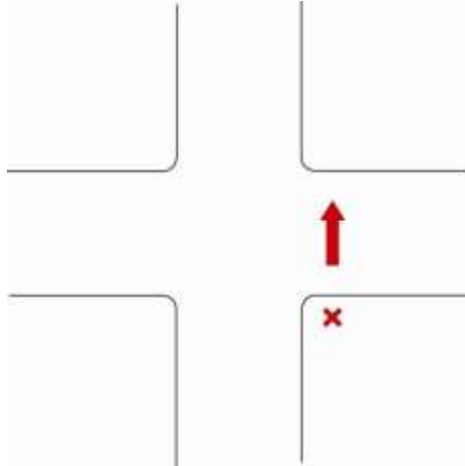


Figure 3-7. Pedestrian Crossing: One Person, One Movement (Observer Denoted as “X”)

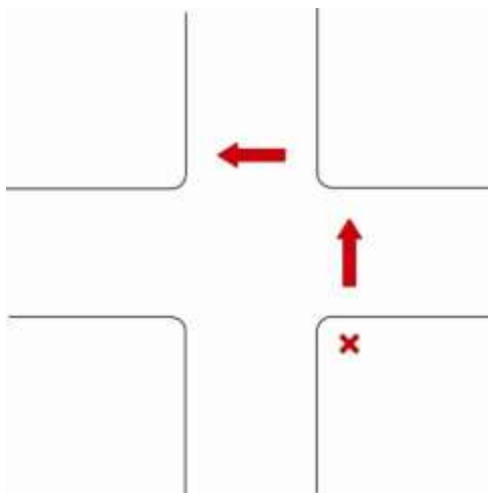


Figure 3-8. Pedestrian Crossing: One Person, Two Movements (Observer Denoted as “X”)

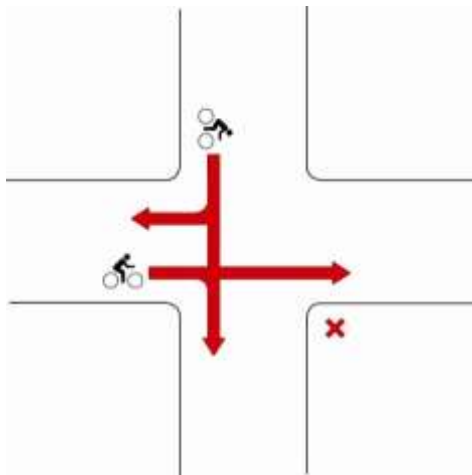


Figure 3-9. Possible Bicycle Movements: Along, To/From, Across (Observer Denoted as “X”)

Table 3-19

Big City Streets Pedestrian & Bicycle Movements Data Collection Parameters

Detail	Street		
	LS	KE	TA
Date	10.23.07	10.11.07	10.22.07
Data collection stations	6	6	6
Observation intervals	9 min	10, 15, 20 min	7, 10, 12 min
	9 min	15 min	10 min
Observation minutes (total)	432 (p, b)	585 (p, b)	427 (p, b)
Sampling period a	11:14	11:03	11:03
	to	to	to
	13:38	13:24	13:38
Sampling period b	16:03	16:00	16:03
	to	to	to
	18:45	18:54	18:12
Weather	Clear	Clear	Partly cloudy
	Clear	Clear	Clear
Temperature	65°F (18°C)	65°F (18°C)	68°F (20°C)
	to	to	to
	75°F (24°C)	75°F (24°C)	83°F (28°C)
Road surface condition	Dry	Dry	Dry
Pedestrian sample size	1,688	4,248	534
Bicycle sample size	58	718	138

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; min = minutes; p = pedestrians; and b= bicycles.

Table 3-20

Small City Streets Pedestrian & Bicycle Movements Data Collection Parameters

Detail	Street		
	SC	CS	CA
Date	09.28.07	09.14.07	10.05.07
Data collection stations	5	11	7
Observation intervals	15 min	10, 15 min	10, 15, 20 min
	11, 14, 15 min	10, 15 min	5, 10, 15 min
Observation minutes (total)	459 (p, b)	570 (p, b)	525 (p) 305 (b)
Sampling period a	11:10 to 13:25	11:00 to 13:05	11:07 to 13:32
Sampling period b	16:00 to 18:25	16:00 to 18:19	16:15 to 18:08
Weather	Cloudy Cloudy	Clear Clear	Partly cloudy Clear
Temperature	63°F (17°C) 67°F (19°C)	72°F (22°C) 76°F (24°C)	58°F (14°C) 61°F (16°C)
Road surface condition	Dry	Dry	Dry
Pedestrian sample size	970	4,469	3,308
Bicycle sample size	44	162	238

Note. CA = California Avenue; CS = Castro Street; SC = San Carlos Avenue; min = minutes; p = pedestrians; and b = bicycles.

Pedestrians sitting, standing, and interacting.

Description: These data were collected by means of observation during walking “tours” of each of the six streets. I undertook most of the tours, generally at a consistent walking speed. Several of the walking tours were undertaken by other members of the study research team, however, which introduced some variability in walking speed. Counts were only taken on one side of the street at a time, the side on which the “touring” surveyor was walking. Pedestrians observed by an approaching surveyor as sitting or standing for at least 10 seconds were counted. Double-counting was avoided by categorizing an individual as sitting or standing if that was the position in which he/she was first observed for the minimum time, even if he/she subsequently changed from sitting to standing or the reverse. Surveyors did their best to remain unobtrusive during survey counting tours, although it was necessary for each of them to carry a clipboard to record data. Some sampling tours, but not all, yielded further data to differentiate types of sitting and standing (including waiting at public transport stops, sitting in outdoor cafes, using cellular telephones, those

related to outdoor cigarette smoking, and people perusing menus posted outside of restaurants).

Pedestrians were counted as interacting when they were observed speaking or gesturing to one another, holding hands, smiling at or waving to one another, or engaged in similar social contact. To minimize obtrusiveness and also to keep up a reasonable touring pace, interactions between people seated together at outdoor restaurants and cafés were not counted. The number of people seated or standing outdoors at restaurants was accounted for, however, in the census of those seated or standing within the effective right-of-way of each street.

No two or more people were counted twice in interacting together or amongst themselves. Both the number of interactions (no double counting) and the number of people involved in the interactions were tabulated. Tables 21 and 22 contain detail on data collection parameters regarding pedestrians sitting, standing and interacting on each street segment. These data were normalized on a per observer hour basis.

Table 3-21
Big City Streets Pedestrians Sitting, Standing and Interacting Data Collection Parameters

Detail	Street		
	LS	KE	TA
Date	10.23.07	10.11.07	11.16.07
	12.05.07	11.26.07	11.22.07
		11.27.07	
		12.03.07	
Observation minutes (total)	241	268	251
Sampling period a	11:00	11:03	11:00
	to	to	to
	13:15	13:24	13:10
Sampling period b	16:29	16:04	16:00
	to	to	to
	18:26	18:23	17:58
Weather	Partly cloudy	Cloudy	Partly cloudy
	Clear	Partly cloudy	Cloudy
Temperature	52°F (11°C)	56°F (13°C)	68°F (20°C)
	to	to	to
	54°F (12°C)	60°F (16°C)	79°F (26°C)
	65°F (18°C)	58°F (14°C)	49°F (9°C)
	to	to	to
	75°F (24°C)	62°F (17°C)	57°F (14°C)
Road surface condition	Dry	Dry	Dry

Note. LS = Lombard Street; KE = King Street – The Embarcadero; and TA = The Alameda.

Table 3-22

Small City Streets Pedestrians Sitting, Standing and Interacting Data Collection

Detail	Street		
	SC	CS	CA
Date	09.28.07 11.07.07	09.14.07 09.18.07	10.05.07
Observation minutes (total)	263	352	363
Sampling period a	11:10 to 13:25	11:00 to 13.12	11:11 to 13:05
Sampling period b	16:04 to 17:55	16:00 to 18:07	16:15 to 18:18
Weather	Cloudy Cloudy	Clear Clear	Clear Clear
Temperature	55°F (13°C) to 67°F (19°C)	68°F (20°C) to 70°F (21°C) 72°F (22°C) to 73°F (23°C)	64°F (18°C) to 77°F (25°C) 72°F (22°C) to 77°F (25°C)
Road surface condition	Dry	Dry	Dry

Note. CA = California Avenue; CS = Castro Street; and SC = San Carlos Avenue.

Crashes and casualties.

Description: Data on total crashes, casualty crashes, crashes involving pedestrians, and crashes involving bicycles were obtained for the period from 1 January 2004 through 31 August 2008 from the California Highway Patrol's Statewide Integrated Traffic Records Systems (SWITRS)⁵². These data were normalized for comparative purposes across the six street segments, as follows:

- per year;
- per mile;
- per million vehicles;
- per estimated million pedestrians; and
- per estimated million bicyclists.

Visual assessment.

Description: I took a set of four digital color photographs of each of the three “larger city” commercial streets and three “smaller city” commercial streets in the

⁵²

Retrieved from the SWITRS web site: <http://www.chp.ca.gov/switrs/switrs2000.html>

research study. Two photographs showed the street and streetscape from each end looking inward (toward the segment being researched) and two photographs showed the street and streetscape from the middle of the street looking outward (toward each end of the research stud segment). The photographs were all taken in the fall and in dry weather, although the time and date of the photographs varied somewhat from street to street. The three sets of larger city and three sets of smaller city commercial street photographs were mounted and shown to all participants in each of three Big City and three Small City commercial street focus groups conducted as part of the research. The purposes, recruitment process, and conduct of these focus group sessions are described in the next section of this chapter. To view all 24 photographs, see Appendix A.

Slideshows of each set of scenes from Big City and Small City streets were also uploaded on the Photobucket web site.⁵³ The larger city and smaller city slideshow Photobucket link for the pertinent street was e-mailed to all those who expressed interest in participating in one of the focus group sessions but were unable to attend, to others who expressed interest in the research study but not a focus group, and to community electronic discussion sites frequented by users of each street (see Appendix B for a list of these sites).

All those who participated in the visual assessment exercise, whether as a member of one of the focus groups or as a recipient of an on-line link, were asked to assign a “grade” to each photograph. “Grading” was done on the standard US academic scale: A (4 points), B (3 points), C (2 points), D (1 point) and F (0 points). Participants were asked to assess each street scene subjectively, purely based on attractiveness and visual appeal. Grades for each street were compared to others within each of the two subsets of streets. Nonparametric tests, as described in a subsequent section of this chapter, were applied to the grading results.

There are many applicable caveats in this kind of assessment, including the effects of the skill of the photographer, the amount of sun or shade at the time the photograph was taken, any differences in visual perspective among the photographs (the angle of the street scene with respect to the street center line, for example), and other factors. As an example of the “other factors”, one of the photographs taken on

⁵³ Information about the photo file sharing service can be retrieved from the Photobucket web site: <http://photobucket.com/>

San Carlos Avenue included a shopping cart left on the sidewalk. I decided to include this scene in the set of four San Carlos Avenue photographs as field experience suggested that shopping carts and other stray objects were often an “unofficial” part of the streetscape at that particular location, which is adjacent to a chain drug store and the store’s street front parking lot. Table 23 summarizes detail on sample sizes for visual assessment of individual streets within the Big City and Small City cohorts.

Table 3-23

Visual Assessment Data Collection

Detail	Street					
	LS	KE	TA	SC	CS	CA
Assessors (# of people)	8	15	17	10	36	31
Cohort	BC	BC	BC	SC	SC	SC

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; SC = San Carlos Avenue CS = Castro Street; CA = California Avenue; BC = Big City; and SC = Small City.

Street user and business assessments.

The experience and opinions of street users⁵⁴ on each of the six street segments were elicited by means of online surveys and focus groups. The surveys were intended to sample perspectives of those who used each street on an array of topics using a questionnaire requiring multiple choice and short narrative answers. In contrast, the focus groups were structured to foster in-depth participant dialog in response to a series of discussion questions. Appendix C provides links to SurveyMonkey electronic survey links and to the blog site associated with the street user’s and business surveys. Those who use these streets only for through passage to some other place are not well represented in these surveys. In my years of experience as a transport planner, eliciting the views of this group is one of the most vexing difficulties in any study.

Focus groups.

Litoselliti (2003) described focus groups as “small structured groups with selected participants, normally led by a moderator” with the purpose of using the interaction within a group “to explore specific topics and individuals’ views and

⁵⁴ Those who used these streets strictly for through motor vehicle travel are most probably under-represented in the survey of street users. At the same time, the duration of stay on each street for these travelers is limited to passing though in a motor vehicle, unlike the experience of those who shop, work, dine, or conduct personal business on the streets.

experiences” (p.1). Focus group participants normally share “certain characteristics and similar levels of understanding of a topic” (Litoselliti, 2003, p. 32). As such, these groups do not represent a random sample of the population. Even if they did, their members “may not even be able to generate meaningful discussions” since some or even many would have no interest at all in the topic (Morgan, 1997, p. 35). Counts of themes or topics raised in focus group sessions are useful in research that aims to “compare distinctly different groups to determine how often various topics are mentioned in different types of groups” (Morgan, 1997, p. 61). Reporting focus group deliberations requires a balance of quotations from participants and summarizing the discussion (Morgan, 1997, p. 64).

Description: Participants in the focus groups were recruited through notices in community electronic discussion sites frequented by users of each street and in electronic editions of newspapers serving the communities within the environs of the street (see Appendix B for a list of these sites). While participation varied by street, a target of from six to twelve participants was set. There was no attempt to make the focus groups representative of the wider population of street users on each of the study street segments. Instead, participation in all but one of the focus groups was open to all who were interested and could attend. The exception was California Avenue, for which almost double the number of people as the target maximum group size of twelve said that they wished to participate. Those who were the latest in expressing interest were advised by e-mail in advance of the focus group session that the meeting was already fully subscribed. All six focus group sessions were conducted in venues either on or in the environs of the subject street segment.

The research purposes of the focus groups were to elicit a set of “themes” and associated quotations pertaining to each research study street segment, as well as participation in the visual assessment exercise described earlier. Thematic information from focus groups is important as qualitative data and can also inform quantitative analysis (Tashakkori and Teddlie, 2003). Each focus group session was audio recorded. I also took written notes during each session. I developed focus group “themes” after review of the notes and recordings. Tables 24 and 25 summarize information about each focus group. Discussion topics introduced to each group were meant to engender discussion on topics related to the research questions listed at the beginning of this chapter. These topics included use, safety, comfort,

convenience, and attractiveness of the street. Appendix D shows the full set of focus group topics.

Table 3-24

Big City Focus Groups

Detail	Street		
	LS	KE	TA
Date	06.28.08	06.21.08	03.15.08
Participants	3	2	6

Note. LS = Lombard Street; KE = King Street – The Embarcadero; and TA = The Alameda.

Table 3-25

Small City Focus Groups

Detail	Street		
	SC	CS	CA
Date	08.03.08	03.29.08	04.19.08
Participants	3	8	10

Note. SC = San Carlos Avenue CS = Castro Street; and CA = California Avenue.

Electronic surveys of street users.

Electronic surveys were prepared on the SurveyMonkey web site⁵⁵ and a link to them disseminated to community electronic discussion sites and newsletters pertinent to users of each street (see Appendices B and C). The introduction to each questionnaire specified the survey purpose and the exact segment of each street pertinent to the survey questions. All of the six street surveys elicited responses on topics related to the research questions listed at the beginning of this chapter. These topics were similar to those raised in the focus groups and included use, safety, comfort, convenience, and attractiveness of the street. Opportunities were provided for open-ended responses in addition to check off box responses (see Appendix E for an example of the survey instrument). Survey responses were compiled in both quantitative form and as a set of themes and illustrative quotations. The survey data analysis procedures are described in a later section of this chapter.

⁵⁵ A description of this electronic survey service can be retrieved from the SurveyMonkey web site: <http://www.surveymonkey.com/>

Business surveys.

Description: Electronic surveys for those with businesses on all six of the study streets were prepared on the SurveyMonkey web site⁵⁶ and also produced in hard copy. A link to these surveys was disseminated to business and merchant's association e-mail lists as available and pertinent to each of the six streets (see Appendix F for a list of these associations). Most of the responses to the electronic survey, however, came from respondents in two streets. Hard copy versions were also hand delivered and distributed by post to businesses on the other four streets. The introduction to each survey specified the survey purpose and the exact segment of each street pertaining to the survey questions. All of the six surveys elicited responses from business owners and operators on topics related to the research questions listed at the beginning of this chapter. These topics included type, hours, and length of tenure of the business, as well as opinions on the business environment and amount of activity on each street. Opportunities were provided for open-ended responses in addition to check off box responses (see Appendix G for a sample of the survey instrument). Table 26 displays the sample sizes by street for both the Street Users' Survey and the Business Survey.

Table 3-26

Survey Data Collection for Street Users and Businesses

Detail	Street					
	LS	KE	TA	SC	CS	CA
Street Users Surveyed	40	73	101	47	127	127
Businesses Surveyed	14	13	16	19	19	16

Note. LS = Lombard Street; KE = King Street – The Embarcadero; TA = The Alameda; SC = San Carlos Avenue CS = Castro Street; and CA = California Avenue.

Population and employment in “catchment” area.

Description: Estimated population and employment within .25 mile or .4 kilometer on either side and from either end of each of the six street segments was derived from countywide transportation forecast models maintained by the SFMTA (King Street - The Embarcadero and Lombard Street), City/County Association of Governments of San Mateo County (San Carlos Avenue), and VTA (California Avenue, Castro Street, and The Alameda). Population and employment estimates for 2007, the year in which most of the data for this research was collected, were derived

⁵⁶ <http://www.surveymonkey.com/>

through interpolation from 2005 estimates to 2015 forecasts (2020 in the case of San Mateo County). Interpolation was done on an equal share for each year (straight line) basis, so that 2007 estimates represented 20% of the projected growth from 2005 through to 2015. While this simplifying assumption masks the reality of uneven annual population and employment growth rates, the resulting estimates across street segments met my *a priori* expectations of comparative population and employment densities based on personal knowledge of the environs of each street.

The population and employment data were obtained at traffic analysis zone (TAZ) geographic level. A .25 mile or .4 kilometer buffer was created in ArcView GIS⁵⁷ around each of the six study street segments. A simplifying assumption was made that the proportion of area buffered within each of the TAZs equaled the population and employment proportion of that TAZ within the buffer. While this assumption simplified the reality of varying densities within TAZs, the resulting estimates across street segments also met my *a priori* expectations based on personal knowledge of the environs of each street. This assessment was confirmed in general terms by means of cursory examination of aerial views of the areas around each street segment as seen in Google Earth.⁵⁸ Appendix H contains maps of each of the six streets showing the .25 mile or .4 kilometer buffers.

The technical steps in the GIS analysis were as follows⁵⁹:

1. Intersect each study buffer with appropriate county TAZ layer and weight each TAZ by the amount of its area contained within the study buffer;
2. Recalculate 2005 and 2015 values for each TAZ based on new study area buffer weights (note that San Mateo County had only 2020 data);
3. Straight line interpolation between 2005 and 2015 (or 2020 in the case of San Mateo County); and
4. Sum all weighed TAZ values within each study area to obtain overall 2007 values.

Data Analysis

The primary and secondary data described above were analyzed with a combination of descriptive and nonparametric statistics. The sample size of only six

⁵⁷ A description of this geographic information system software can be retrieved at the ArcView web site: <http://www.esri.com/software/arcview/>

⁵⁸ Information about this mapping tool can be retrieved at the Google Earth web site: <http://earth.google.com/>

⁵⁹ Data used for this interpolation are available in the URDMS Curtin University research data repository.

streets for the comparative metrics on street characteristics and use ruled out assumptions concerning the distribution (e.g. normality) of the data (Leach, 1979). This small number precluded parametric statistical analysis of the variables across the sample of streets. Further, the ordinal rather than interval or continuous nature of the Likert-scale data obtained in the Visual Assessment survey, as well as the Street User's survey required reliance on nonparametric rather than parametric analysis (Jamieson, 2004 and Allen, 2007). Chapter 5 contains findings from all statistical analyses conducted in this research. The statistical procedures used in each category of data are discussed in the material to follow.

Metrics on street characteristics and use.

Each of the 47 metrics listed in Table 27 is described in bar chart and tabular form across the six streets in this research and within each of the two sub-groups of streets. These metrics were also treated in nonparametric statistical tests. The non-parametric procedures used comprised the Mann-Whitney U or Wilcoxon Rank Sum⁶⁰ test and Spearman's Rank Order test. The Mann-Whitney-Wilcoxon Rank Sum and the Spearman's Rank Order tests were based on rank order data from independent samples with continuous distributions (Gibbons, 1993a and 1993b). Each of these tests is summarized below.⁶¹

Mann-Whitney-Wilcoxon test.

Pedestrian activity, bicycle use and public transport patronage for the two test street segments was compared to four control street segments by use of the Mann-Whitney-Wilcoxon Test. This procedure is the nonparametric equivalent of the t-test (Gibbons, 1993b). A .05 level of significance was set for application of this test in deriving the one-sided Wilcoxon Exact p (probability) value that the distribution of ranks between these two groups does not differ significantly.

Spearman's rho.

Subsets of Comparative Street Characteristics and Use metrics were used to test the degree of association between a number of hypothesized dependent variables and hypothesized independent variables that have been paired with them in studies summarized in Chapter 2. The hypothesized dependent variables are shown with

⁶⁰ The Mann Whitney U and Wilcoxon Rank Sum test are equivalent statistical tests. Retrieved from the Handbook of Biological Statistics website: <http://udel.edu/~mcdonald/statkruskalwallis.htm>

⁶¹ As the nonparametric tests used in this research require continuous data distributions, the metric "Subjective Rating of Informal Outdoor Seating Capacity" could not be used for any of these tests.

their hypothesized independent variables in Tables 28 through 30. The Spearman's Rank Order Test was used in this analysis.

The Spearman's Rank Correlation Coefficient (Spearman's Rho) compares the degree of association between two sets of rankings. It should be emphasized that Spearman's Rho is a test of association, not an attempt to explain the relationship between variables (Gibbons, 1993a). Spearman's Rho is the nonparametric equivalent to Pearson's Product Moment Correlation as applied to ranked data (Gibbons, 1993a). The value of Rho can range from -1 to +1. A .05 level of significance was set for application of this test.

Table 3-27

Comparative Street Characteristics and Use Data

Category	Metric
Street segment and ROW characteristics	Street segment length # of through lanes ROW %, motor vehicle (net) ROW %, pedestrians (dedicated) ROW %, bicycle use and shared use with pedestrians ROW %, public transport (dedicated) ROW %, nature (permeable) ROW %, tree canopy
Modal use	AADT 85 th percentile motor vehicle speeds, mid-section % trucks (3 or more axles) Daily public transport boardings, on street per mile and per km Daily public transport frequency, on street Daily public transport frequency, adjacent Daily regional and intercity passenger rail frequency # public transport stops per mile and per km # pedestrians walking along street # pedestrians walking across street # pedestrians walking, total # pedestrians sitting # pedestrians standing Total # pedestrians walking, sitting, or standing (pedestrian presence) # pedestrian interactions # pedestrians involved in interactions # bicyclists crossing street # bicyclists along, to, and from street Total # of bicyclists along, to, and from street
Street frontage characteristics and area context	% of discontinuous street frontage (gaps) % of street frontage in “green” gaps % of at-grade street buffer Retail frontage, linear feet per mile and per km Restaurant frontage, linear feet per mile and per km Vacant building frontage, linear feet per mile and per km # doorways per mile and per km
	(continued)

Table 3-27

Comparative Street Characteristics and Use Data (continued)

Category	Metric
Street frontage characteristics and area context	Active, “transparent” windows, linear feet per mile and per km # pedestrian lateral connections, per mile, km # commercial driveways, per mile and per km # crosswalks across, per mile and per km # crosswalks along, per mile and per km # signalized crossings per mile and per km # bicycle storage racks per mile and per km Intersection density (# legs within .25 miles, .4 km # outdoor café chairs per mile and per km # outdoor public benches per mile and per km Subjective rating of informal outdoor seating capacity Population within .25 miles, .4 km buffer of street segment centerline and each end Employment within .25 miles, .4 km buffer of street segment centerline and each end

Note. AADT = annual average daily traffic; ROW = right-of-way and km = kilometer.

Table 3-28

Metrics Associated with Pedestrians Walking, Sitting, Standing, and Interacting

Category	Metric
Street segment and ROW characteristics	# of through lanes ROW %, pedestrians (dedicated) ROW %, bicycle use and shared use with pedestrians ROW %, nature (permeable) ROW %, tree canopy
Modal use	AADT 85 th percentile motor vehicle speeds, mid-section Daily public transport frequency, on street Daily public transport frequency, adjacent Daily regional and intercity passenger rail frequency # public transport stops per mile and per km
Street frontage characteristics and area context	% of discontinuous street frontage (gaps) % of street frontage in “green” gaps % of at-grade street buffer Retail frontage, linear feet per mile and per km Restaurant frontage, linear feet per mile and per km Vacant building frontage, linear feet per mile and per km # doorways per mile and per km Active, “transparent” windows, linear feet per mile and per km
Street frontage characteristics and area context	# pedestrian lateral connections, per mile and per km # commercial driveways, per mile and per km # crosswalks across, per mile and per km # crosswalks along, per mile and per km # signalized crossings per mile and per km Intersection density (# legs within .25 miles, .4 km) # outdoor café chairs per mile and per km # outdoor public benches per mile and per km Population within .25 miles, .4 km buffer of street segment centerline and each end Employment within .25 miles, .4 km buffer of street segment centerline and each end

Note. AADT = annual average daily traffic; ROW = right-of-way; and km = kilometer.

Table 3-29

Metrics Associated with Bicycling

Category	Metric
Street segment and ROW characteristics	# of through lanes ROW %, bicycle use and shared use with pedestrians
Modal use	AADT 85 th percentile motor vehicle speeds, mid-section % trucks (3 or more axles)
Street frontage characteristics and area context	# commercial driveways, per mile and per km # signalized crossings per mile and per km # bicycle storage racks per mile and per km Intersection density (# legs within .25 miles, .4 km Population within .25 miles, .4 km buffer of street segment centerline and each end Employment within .25 miles, .4 km buffer of street segment centerline and each end

Note. AADT = annual average daily traffic; ROW = right-of-way; and km = kilometer.

Table 3-30

Metrics Associated with Public Transport Boardings

Category	Metric
Street segment and ROW characteristics	ROW %, public transport (dedicated)
Modal use	Daily public transport frequency, on street Daily regional and intercity passenger rail frequency # public transport stops per mile and per km
Street frontage characteristics and area context	Retail frontage, linear feet per mile and per km Restaurant frontage, linear feet per mile and per km Population within .25 miles, .4 km buffer of street segment centerline and each end Employment within .25 miles, .4 km buffer of street segment centerline and each end

Note. ROW = right-of-way and km = kilometer.

As described in Chapter 5, some of the hypothesized independent variables were grouped into two separate indices (Design and Streetscape) that were each evaluated for degree of association with hypothesized dependent variables using the Spearman's Rho test. Ranking by street segment on each category or index of variables was compared to the ranking of pedestrian, bicycle, and public transport use.

Traffic safety data.

The crash data for all six street segments were analyzed with descriptive and non-parametric statistics. As with the comparative street metrics described above, the sample size of only six streets use ruled out assumptions concerning the distribution (e.g. normality) of the data and thus also excluded parametric statistical analysis of the variables across the sample of streets. Instead crash variables are described in bar chart and tabular form across the six streets in this research and within each of the two sub-groups of streets. The Spearman's Rho Test was applied to test the association of ranks in pedestrian and bicycle activity metrics to ranks in crash data.

The crash sets were as follows:

- crashes per year per mile;
- crashes per mile per million motor vehicles;
- casualties from crashes per year per mile;
- casualties per mile per year per million motor vehicles;
- casualties per crash;
- bicycle - vehicle crashes per year per mile;
- pedestrian - vehicle crashes per year per mile;
- bicycle - vehicle crashes per year mile per million motor vehicles;
- pedestrian - vehicle crashes per year per mile per million motor vehicles;
- bicycle crashes per mile per million pedestrians;
- pedestrian crashes per mile per million pedestrians;
- share of annual bicycle crashes subtracted from share on annual bicycle volumes for each street segment (Bicycle Safety Index); and
- share of annual pedestrian crashes subtracted from share on annual pedestrian volumes (Pedestrian Safety Index).

Visual assessment.

The visual assessment ratings are displayed in charts and tables for each subset of three streets and also analyzed with nonparametric statistics: the Mann-Whitney-Wilcoxon tests for differences in ranks of streets by visual assessment score.

Street user's surveys.

Responses in each category ("Very", "Somewhat", and "Not at All") are shown on bar charts and tables for each subset of three street segments. The proportion of "Very Comfortable", "Very Safe", etc. answers was analyzed with a one-tailed difference in proportions z test, a parametric statistical procedure (Brase & Brase, 2006) between pairs of street segments within each subgroup.

Business surveys.

The responses in each category ("Excellent", "Good", "Fair" and "Poor") are shown on bar charts and tables for each subset of three street segments. The first two responses are collapsed into one category and the last two into a second category for the purpose of conducting a Fisher's Exact test of the difference of proportions between street segments (Leach, 1979). This nonparametric test was used to evaluate whether or not the two categories of street segment assessment are independent of one another.

New indicators of active, sustainable streets.

This dissertation proposes two new indicators of active, sustainable streets. The first is the ratio of motor vehicle drivers to people not in motor vehicles along a street. The second is the ratio of motor vehicle drivers to those who board public transport on a street. Each is an indicator of the balance between use of a street by personal motor vehicles and use by people apart from the automobile. In other words, each measures the degree of car infusion or car dependence on a street. As these ratios fall, so does the degree of car dominance. These metrics were calculated as follows:

Ratio of Motor Vehicle Drivers to People Out of Motor Vehicles = (weekday motor vehicles per hour_{ob} / average # of pedestrians along a street per hour_{ob} + average pedestrians across a street per hour_{ob} + average # of people standing along a street per hour_{ob} + average # of people sitting along a street per hour_{ob} + average # of bicyclists along/to/from and across a street per hour_{ob}).

Where hour_{ob} = the hourly average for the field data collection (observation) hours.

Derivation of weekday motor vehicles per hour is as follows:

AADT * % of weekday personal travel that takes place during an average hour⁶² for the field data collection hours.

Pedestrian and bicycle counts, normalized on a per observer hour basis, were taken in the field.

Ratio of Motor Vehicle Drivers to Public Transport Boardings = (weekday motor vehicles per hour_{ob} / public transport boardings along a street per hour_{ob})

Derivation of weekday public transport boardings for the field data collection hours is as follows:

Weekday public transport boardings per year * % of weekday personal travel that takes place during an average hour (see above) for the field data collection hours.

As both street lengths and number of public transport stops varied by street, public transport boardings were normalized on a per mile basis.

Because of time and resource limitations on data collection, these ratios are necessarily based on a snapshot of conditions along each street. Based on my extensive experience both observing and using each of these streets, however, these indicators are broadly representative of the real differences in car dominance across the sample of six streets.⁶³

Conclusion

Analysis and data collection methods discussed in the preceding sections are suitable for comparing a small number of street sections along an extensive array of variables. In this approach, each street section can be examined in detail as well as be compared in depth to other street sections in order to illuminate similarities and differences. Such an approach is highly useful in suggesting relationships among a

⁶² As there is no data set available on diurnal travel along the six streets, proxy data were calculated from 2001 National Household Travel Survey data on distribution of person trips in the US by time of day. The average hourly share of daily person trips during the hours 11 AM to 2 PM and 4 PM to 7 PM was 7.17 %. Retrieved from the U.S. Department of Transportation Bureau of Transportation Statistics (BTS) web site: http://www.bts.gov/publications/highlights_of_the_2001_national_household_travel_survey/html/table_a12.html

⁶³ This use of experience and judgment, professional and personal, to assess empirical findings may be described as work of a “reflective practitioner” (Schön, 1983).

great many variables that potentially influence how streets are used. This kind of in-depth evaluation is called for to do justice to the complex roles streets play as links for travel and places for people. As the sample size of street sections was limited, however, the “deep but narrow” framework was not suitable to define cause-and-effect relationships quantitatively. For that definition, parametric statistical analysis on a much more extensive set of street sections would be required. Chapter 5 presents both quantitative (descriptive and non-parametric statistics) and qualitative (perspectives offered in focus groups and questionnaires) assessment findings from this research study of six commercial arterial street sections in five cities on the San Francisco Peninsula. These streets are described with visuals in the next chapter.

Six Streets

Figure 4-1. Location of Six Streets in This Research

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King Street - The Embarcadero.

King Street - The Embarcadero is a boulevard completed in 2002 to replace the Embarcadero Freeway, which was badly damaged in the 1989 Loma Prieta earthquake (The Preservation Institute, n.d.; Congress for the New Urbanism, n.d.). Figure 2 depicts a part of the remains of the Embarcadero Freeway following Loma Prieta. The boulevard section studied in this dissertation was designed to accommodate two through lanes of motor vehicle traffic in each direction, light rail tracks each way, bicycle lanes on both sides, and wide sidewalks (see Figure 3). A close-up view of this street section is shown and in its wider context in Figures 4 and 5, respectively. King Street - The Embarcadero was designed as a “complete street”, in most respects the inverse of the Embarcadero Freeway it replaced.



Figure 4-2. The Embarcadero Freeway after the 1989 Loma Prieta Earthquake
Copyright 2006 Telstar Logistics (Photo via Flickr).



Figure 4-3. King Street - The Embarcadero in 2007

Photograph by the author.



Figure 4-4. King Street - The Embarcadero: Close Environs

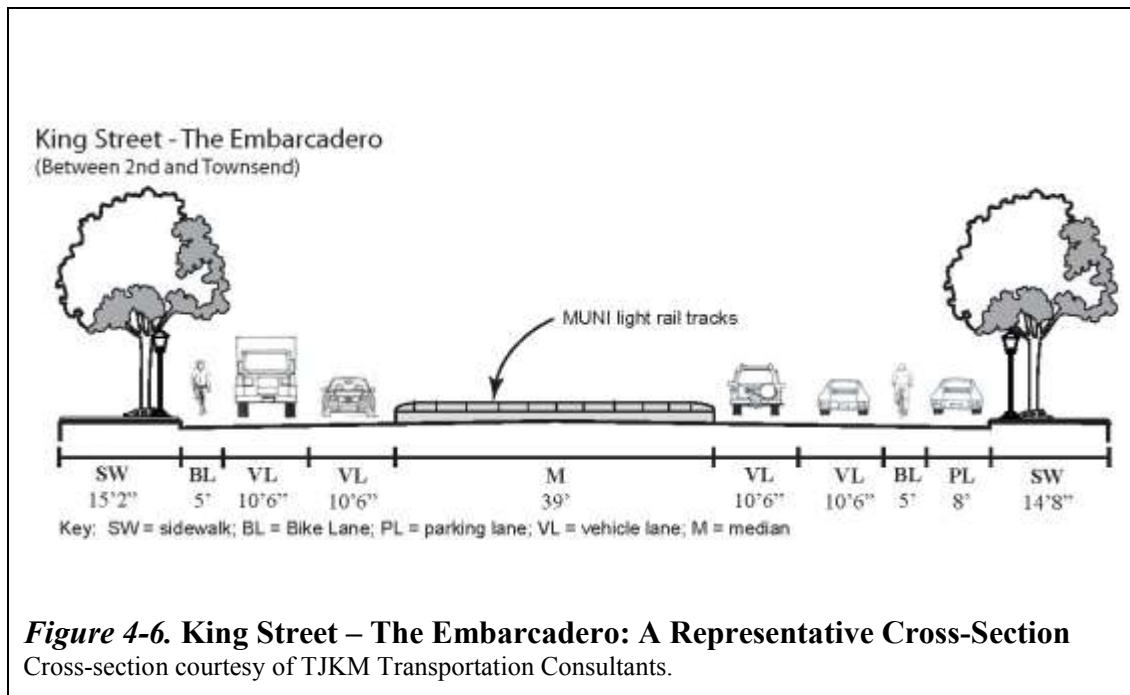
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Figure 4-5. King Street - The Embarcadero: Wider Environs
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Characteristics and use.

King Street - The Embarcadero functions as an urban arterial street extension of the interstate freeway, I-280, one of the two freeways that connect San Jose and intermediate areas along the San Francisco Peninsula to downtown San Francisco. The estimated average annual daily traffic volume on the section between Brannan and 3rd Street evaluated in this research is 43,000 vehicles. The motor vehicle speed limit on this section is 30 mph or 48 kph. I measured the mid-section off-peak 85th percentile speed at 35 mph or 56 kph. As described previously, the street has two motor vehicle travel lanes in each direction, two light rail tracks down the center, and bicycle lanes along each side. Considerable space in the typical 158.4 foot (48.3 meter) cross-section from the building edge of the sidewalk on one side to that of the other on this street segment is devoted to uses other than the private motor vehicle. Accommodation for these uses include sidewalks widths of 13.0 to 14.8 feet (4.0 to 4.5 meters) on the west side and 15.2 to 27.0 feet (4.6 to 8.2 meters) on the east or Bay side; 35.7 feet (10.9 meters) of center median, much of which is light rail track, platforms, and raised buffer area; and bike lanes of 5.0 feet or 1.5 meters in each direction. Figure 6 illustrates the cross-section of a portion of King Street – The Embarcadero.



King Street - The Embarcadero is an important commuter route for SFMTA (better known locally as Muni) light rail passengers (see Figure 7) travelling to and from downtown San Francisco and the Caltrain commuter rail station at 4th and King, one long block south of the study section. The street is the setting for offices, restaurants, shops, and multi-family residential buildings. It is also within walking distance of the Mission Bay campus of the University of California, San Francisco, a center for health research and education located to the southeast of the study segment. The most notable land use on the street is ATT Park, home of San Francisco's major league baseball team, the Giants. Various medium and high-rise residential condominium projects have been built on King Street - The Embarcadero or in the surrounding South Beach, Mission Bay, and South of Market neighborhoods since King Street -The Embarcadero was constructed.

In 2007, an estimated 12,496 people worked and 5,184 lived within a .25 mile (.4 kilometer) band on each side and at each end of the research section of King Street - The Embarcadero. This number equates to population and employment densities of 9,781 people and 23,575 jobs per square mile (or 38 and 91 per hectare, respectively). The 2008 median household income in the two neighborhoods, South Beach and Mission Bay, that surround the street, the smallest geographic unit available in the nearest year to the year during which field data were collected, was \$101,543, or about 66% more than the California median household income of

\$61,021 for that year (City-Data, 2010; US Census Bureau, 2009). This figure is likely influenced by the proximity of new condominium projects built on and near the street as part of the redevelopment and gentrification of this part of the San Francisco waterfront.



Figure 4-7. King Street - The Embarcadero: Weekday Scene
Photograph by the author.

Alternatives to the single-occupant automobile were predominant for King Street - The Embarcadero street user's surveyed in this research. More than three-quarters reported that they frequently walked along the street (see Figure 8), about two-fifths used the light rail often, and more than two-fifths were frequent bicyclists on the bike lanes and wide sidewalks of King Street - The Embarcadero. In contrast, fewer than 20% frequently drove this street section. This preference by the predominantly local respondents to the street user's survey for more sustainable travel modes contrasts with the comparatively high motor vehicle traffic volumes manifest on the street. This is likely due to the function of King Street – The Embarcadero as a surface street extension of a major freeway. Seventy-two percent of survey respondents who reported a residence lived in neighborhoods close to King

Street - The Embarcadero and the remainder were from other areas of San Francisco and the Bay Area.⁶⁵



Figure 4-8. Walkable King Street - The Embarcadero

Photograph by the author.

The three most popular reasons for using King Street - The Embarcadero reported by street user's survey respondents were shopping, dining, and attending events at ATT Park (see Figure 9). It is likely, however, that some of the shopping and dining reported by these respondents took place on the block between 3rd Street and 4th Street, much of which is located a short distance outside of the study area boundaries for this research. King Street - The Embarcadero is the venue not only for professional sports, but the street itself is closed at times for special events such as foot races (see Figure 10) and City-sanctioned "street parties", Sunday events during which motor vehicle traffic is banned.⁶⁶

⁶⁵ A complete set of survey results for King Street - The Embarcadero and for the other five streets in this research is available in the URDMS Curtin University data repository.

⁶⁶ Retrieved from the SF Gate web site:
http://articles.sfgate.com/2010-03-15/bay-area/18831586_1_embarcadero-street-closure-san-francisco



Figure 4-9. King Street - The Embarcadero at ATT Park on Game Day
 Photograph by the author.



Figure 4-10. King Street - The Embarcadero as a Community Events Venue
 Photograph by the author.

During field work and also as a bicycle, pedestrian, and public transport commuter on this street in past years, I enjoyed my time on King Street - The Embarcadero. The wide sidewalks, bicycle lanes, and light rail platforms and trains gave me a sense that I was welcome to journey along the street even though not driving a motor vehicle. I thought that the views within the street right-of-way as well as beyond it to the San Francisco Bay were extraordinary.

Lombard Street.

The section of Lombard Street surveyed for this research is owned and maintained by the California Department of Transportation (Caltrans). The five-block section of Lombard from Broderick to Fillmore, the portion closest to the Highway 101 on/off-ramps, was selected as one of the two control streets for comparison purposes to King Street - The Embarcadero in the Big City cohort. Figures 11 and 12 display this segment of Lombard in zoom-in, zoom-out views.

Ten blocks east of Fillmore, the eastern limit of the section studied in this dissertation, Lombard Street becomes the famed “Crookedest Street in the World”, well known since 1922 for its cobblestone switchbacks (Brown-Martin, 2001). Lombard Street, located southeast of the Golden Gate Bridge in the northern portion of San Francisco, separates the Marina District to the north from the Cow Hollow neighborhood to the south. It has three through lanes in each direction and on-street parking lanes on both sides, but no bicycle lanes, in the section between Broderick and Fillmore, as shown in Figure 13. A median landscaping project was completed on Lombard Street by the San Francisco Department of Public Works in 2006 (San Francisco Public Works Department, 2006). Figure 14 displays this median after landscape improvements. Public bus transport services are operated along Lombard by SFMTA and by the Golden Gate Bridge Highway and Transportation District. There is no rail passenger service along or within two miles or 3.2 kilometers of Lombard Street.

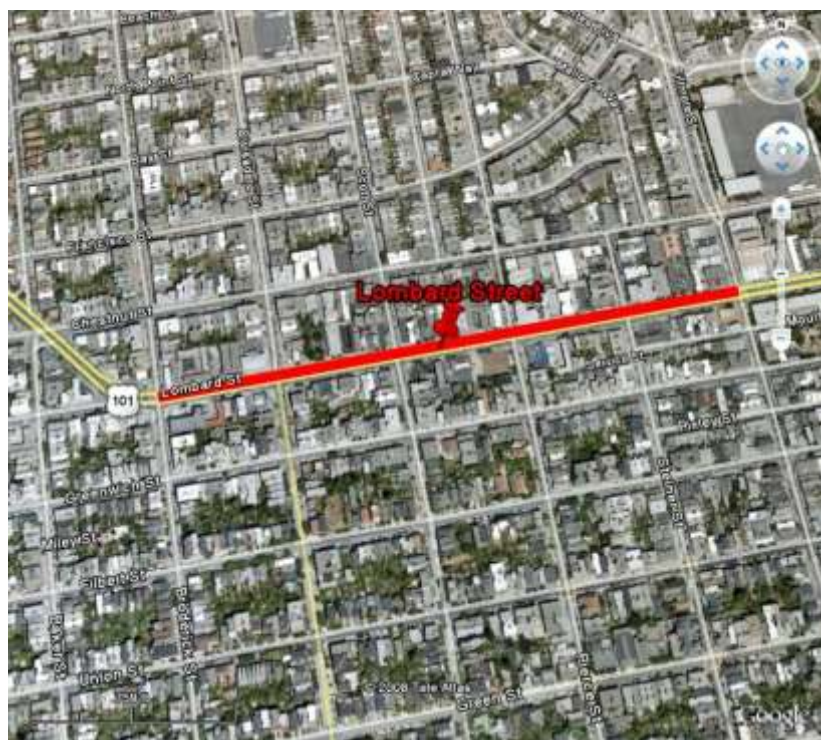


Figure 4-11. Lombard Street: Close Environs

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Figure 4-12. Lombard Street: Wider Environs

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Figure 4-13. Lombard Street: Looking East
 Photograph by the author.

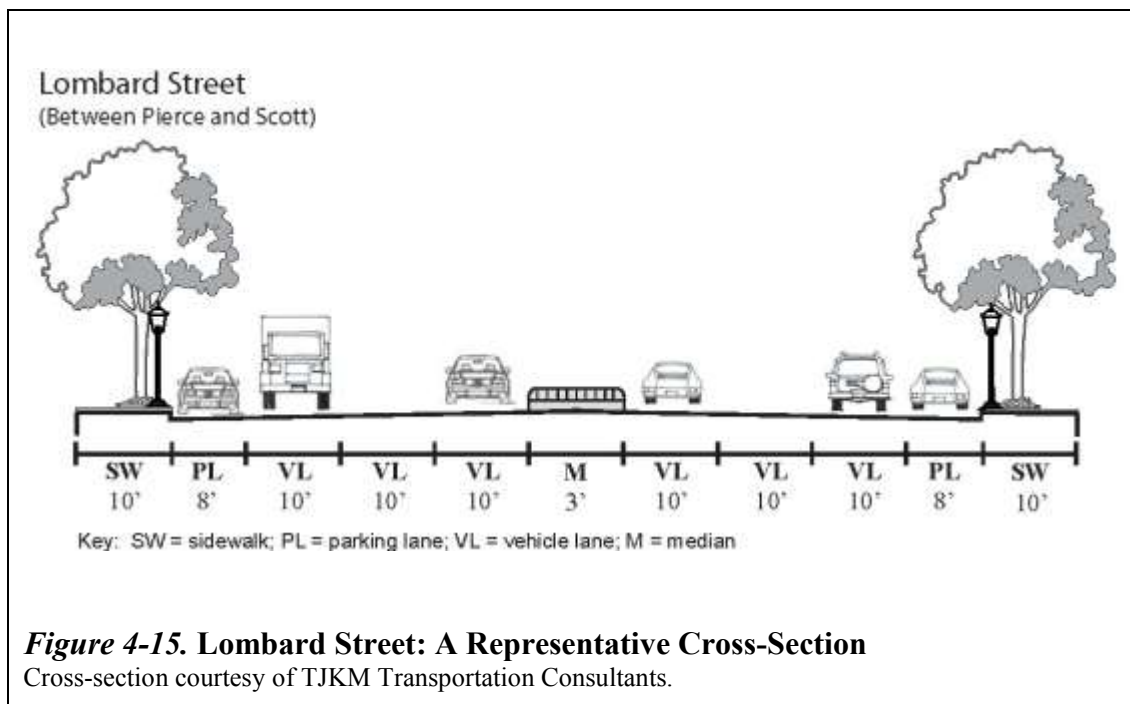


Figure 4-14. Lombard Street: View of Median
 Photograph by the author.

Characteristics and use.

Similar to King Street - The Embarcadero, the twelve blocks of Lombard Street between Broderick and Van Ness – including the five-block section from

Broderick to Fillmore studied in this dissertation - serve as a surface street extension of a freeway into and out of San Francisco. The typical cross-section of this segment of Lombard Street includes sidewalk width of 10 feet (3 meters) on each side, median width of 3 feet (1 meter), and average travel lane width of 12.7 feet (3.9 meters). Figure 15 presents a typical street cross-section on Lombard. As displayed in Figure 16, usable sidewalk widths are often narrow because of placement of signs and other appurtenances.



An annual daily average of approximately 41,000 motor vehicles travel on Lombard Street, many of which make the through trip between Marin and Sonoma Counties to the north of the Golden Gate Bridge to and from the Financial District in downtown San Francisco. I measured off-peak 85th percentile motor vehicle speed mid-segment at 33 miles or 53 kilometers per hour. The speed limit on Lombard is 30 mph or 48 kph.

Land use on Lombard Street includes such auto-oriented establishments as motels, auto service repair shops, and fast-food restaurants, as well as an eclectic mix of storefront businesses interspersed with some multifamily residential units. Figure 17 shows a snapshot of the Lombard streetscape. The environs of Lombard are mainly residential, with the notable exception of Chestnut Street, which is a popular café and retail destination parallel to Lombard one block to the north. In 2007, an estimated

10,081 people lived and 4,609 worked within a buffer area of a quarter of a mile (.4 kilometer) from each side and each end of the segment of Lombard Street under study. This equals a density of 21,002 persons and 9,602 workers per square mile (or 81 and 37 per hectare, respectively). The median household income in 2008 for the Marian and Cow Hollow neighborhoods surrounding the street was \$110,704, or about 81% more than California's median household income (City-Data, 2010; US Census Bureau, 2009). This statistic reflects affluence of the households who reside in these two desirable San Francisco neighborhoods. Lombard Street is alone amongst the six streets evaluated in this dissertation in hosting no street festivals or other civic events requiring that it be closed to motor vehicle traffic for any period of time during the year.



Figure 4-16. Lombard Street: Sidewalk Conditions
Photograph by the author.



Figure 4-17. Lombard Streetscape
 Photograph by the author.

The predominance of Lombard Street User’s Survey respondents, about three-fifths for each mode, accessed the street by driving or by walking. One out of every seven frequently came to Lombard by bus and fewer than one in ten by bicycle. Three-quarters of the respondents often visited the street to dine and two-fifths to shop. Just over one-third came to Lombard for either personal or professional services. About half of survey respondents lived in a nearby neighborhood and the remainder in other San Francisco neighborhoods or elsewhere in the Bay Area.

During my field work I found Lombard Street to be inhospitable because of the noise and proximity of motor vehicle traffic. I needed to be on guard at every moment as a pedestrian or bicyclist due to the dominance of cars, trucks, and buses. Each time I walked the street, it felt as though I were relegated to a narrow track alongside a motor vehicle torrent.

The Alameda.

The Alameda, San Jose’s and possibly California’s first street, was established in the late eighteenth century as a link between the Pueblo of San Jose and the Mission Santa Clara, three miles away. This historic road was part of El Camino Real, the famous track that connected the missions of coastal California. The Alameda has served both a communications function and a civic role as site of state

fairs and cycling competitions ever since (Clark 2006, pp. 1-2). Even today a segment of the street outside of the study limits for this research hosts the July 4th Rose, White, and Blue Parade and Festival.⁶⁷ The study section itself hosts a portion of the annual San Jose Half Marathon.⁶⁸ Figures 18 and 19 show closer and further views, respectively, of The Alameda.

The Alameda is currently owned and maintained by Caltrans, but state legislation has been enacted to transfer ownership responsibilities to the City of San Jose.⁶⁹ A recent conceptual plan for re-design of The Alameda has recommended an eventual cross-section of one through lane in each direction with intermittent left turn pockets, bicycle lanes, parking lanes and urban design amenities for the Town Center segment, which includes the section between Race and Stockton studied in this dissertation (BMS Design Group and Kimley-Horn Associates, 2010, p. 3.9). Figures 20 and 21 depict representative portions of the current cross-section of The Alameda.



Figure 4-18. The Alameda: Close Environs

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⁶⁷ Retrieved from the Alameda Business Association web site:
<http://www.the-alameda.com/parade.html>

⁶⁸ Retrieved from the Dodge Rock N' Roll Half Marathon web site:
<http://san-jose.competitor.com/?l=right>

⁶⁹ Retrieved from the City of San Jose web site:
<http://www.leginfo.ca.gov/cgi-bin/postquery>

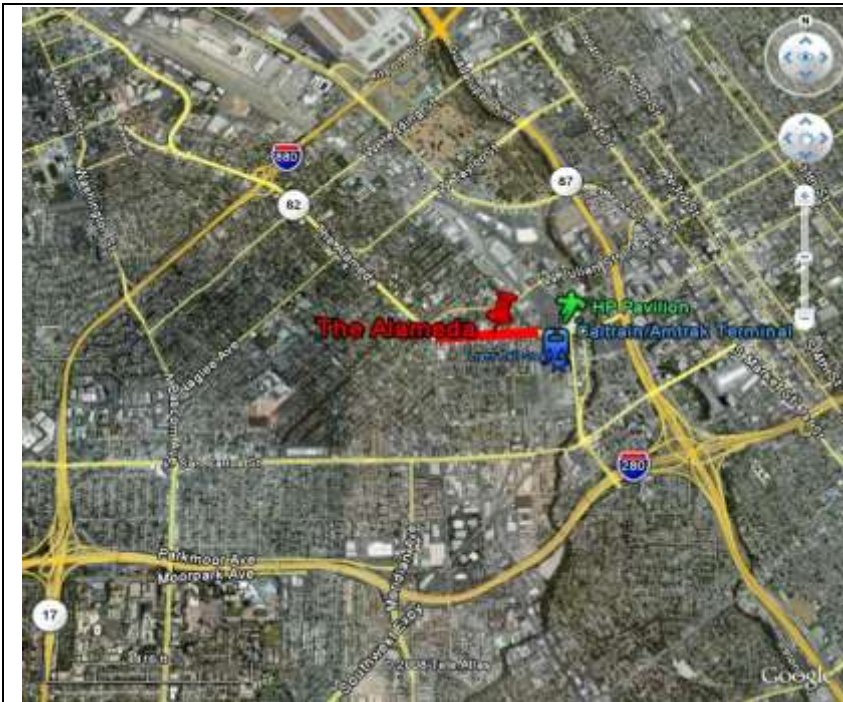


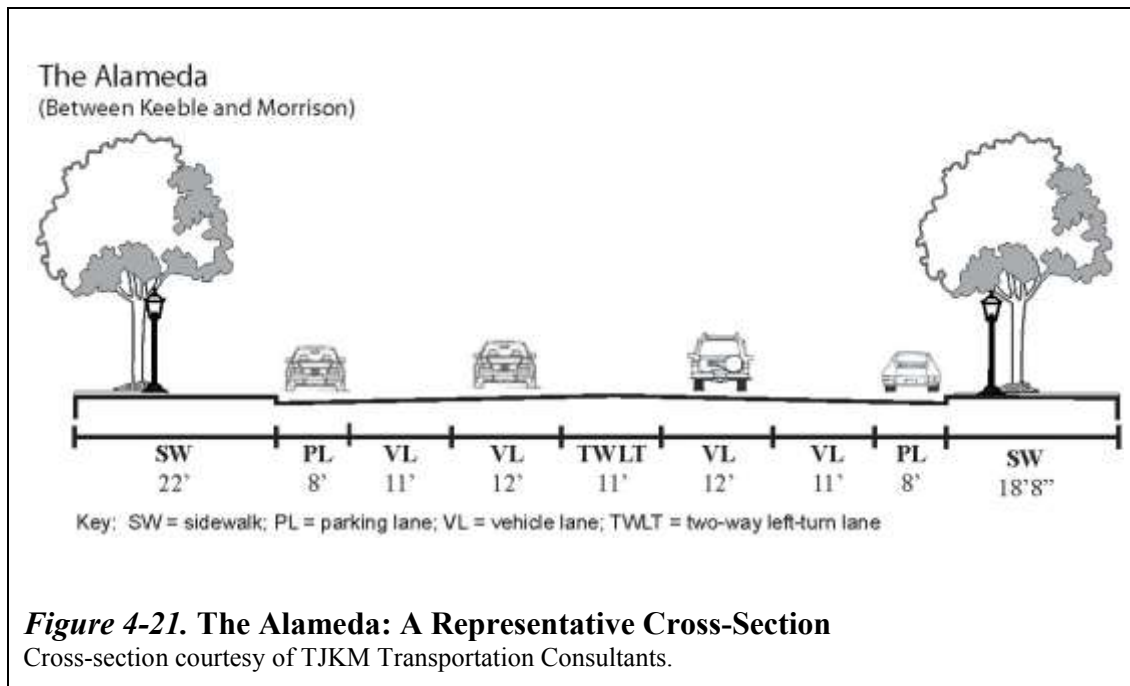
Figure 4-19. The Alameda: Wider Environs

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Figure 4-20. The Alameda: Geometry

Photograph by the author.



Characteristics and use.

Similar to King Street - The Embarcadero with respect to San Francisco, The Alameda is a commuter corridor to downtown San Jose. Also like the former street, The Alameda is within walking distance of a major commuter and light rail station. While The Alameda is primarily a commercial street, its environs on three sides are residential. The fourth side comprises a portion of downtown San Jose that includes two important activity centers: Diridon Station and the HP Pavilion, home of the National Hockey League's San Jose Sharks. This area is the focus of intensive planning for future high-speed rail service to Diridon Station and a hoped-for major league baseball park (City of San Jose, 2009).⁷⁰

The Alameda experiences estimated average annual daily traffic volumes of 15,600 vehicles, far fewer than either King Street - The Embarcadero or Lombard Street. I measured off-peak 85th percentile mid-section speeds on The Alameda at 38 mph or 61 kph, faster than either of the other two Big City street sections. The Alameda is subject to a speed limit of 35 mph or 56 kph.

Like King Street - The Embarcadero, The Alameda has two through lanes in each direction with center left turn lanes at cross street intersections. There is parking on both sides of the street, but no bicycle lanes or street space dedicated for exclusive

⁷⁰ Information about the potential new baseball stadium in the Diridon station vicinity can be retrieved from City of San Jose, Redevelopment Agency web site:
<http://www.sjredevelopment.org/ballpark.htm>

public transport use. The Alameda hosts the Santa Clara Valley Transportation Authority (VTA) Rapid 522 Line, an express urban bus transit service, which terminates at the Diridon Station in downtown San Jose.⁷¹

The typical sidewalk width on this section of The Alameda is 18 feet (5.5 meters). Widths for motor vehicle travel lanes and left turn lanes are 12 feet (3.7 meters) and 11 feet (3.4 meters), respectively. Parking lane width is 8 feet (2.4 meters). There is a short center median segment of 5 feet (1.5 meters) between Race and Keeble. Figure 22 shows these space allocations.

The quarter-mile width from each side and end of The Alameda contained 3,069 people and 3,196 jobs in 2007, making this street section environs the least developed in the Big City cohort. The equivalent population and employment densities per square mile (1.6 kilometer) were 6,600 and 6,873, respectively (or 25 and 26 per hectare, respectively). Median household income in 2008 for Alameda, St. Leo's, Shasta Hanchett Park, and Garden Alameda, the four neighborhoods in closest proximity to The Alameda, was \$60,966, lowest of the six streets in this dissertation research, and very close to the median income for the State of California (City-Data, 2010; US Census Bureau, 2009).

More than three-quarters of respondents to The Alameda Street User's Survey reported that they frequently travel to The Alameda by car, one fifth by bike, and three-fifths on foot. Just 3% reported that they frequently access the street on public transport. Three-fifths of respondents reported that they often dined along The Alameda, three-fifths shopped, and about one-fifth used professional or personal services there. Almost all of the survey respondents resided in nearby neighborhoods.

During my field work I found The Alameda to be easy to walk along because of its wide sidewalks and tree canopy, but at times uncomfortable to cross due to motor vehicle speeds. I did not feel comfortable cycling along the street for the same reason.

⁷¹ Information about the Rapid 522 Line can be retrieved from the VTA web site: <http://www.vta.org/projects/line22brt.html>



Figure 4-22. The Alameda: Space Allocation

Photograph by the author.

Castro Street.

In 1990, Castro Street began a transformation, at a cost of \$12 million, from a “desolate and bleak” Small City downtown street to being the core of one of “the most successful downtown revitalizations in the state” (Perry, 2006, pp. 78-79). This transformation had a new street cross-section at its core. Castro Street in downtown Mountain View was re-designed from two through lanes in each direction and a parallel parking lane on each side to one lane in each direction, a center left turn lane at intersections, and a “flex-zone” curb side that could be used for parking or restaurant café space (see Figure 23). A new Performing Arts Center and City Hall civic center complex was built at the corner of Castro Street and Mercy Street as public investment catalysts for Castro’s revival (Perry, 2006, p. 80).

Arguably, this re-design is an early example of the “context-sensitive” street design phenomenon in the United States. Prior to the Castro Street project, Mountain View had been no different from other American cities, big and small, in making more and more room for motor vehicles (McShane, 1994). Photographs of Castro Street from 1927 and 1937 show two through lanes in each direction and angled parking on each side (Perry, 2006, p. 68). By 1950, there were two through lanes and a parallel parking lane on Castro Street (Perry, 2006, p. 73). Figures 24 and 25 show

the contrast in Castro Street's cross-section in 1957 compared to 2007, the year fieldwork was completed on the street for this dissertation. Figures 26 and 27 display the closer and further environs of Castro Street.



Figure 4-23. Castro Street “Flex-zone”: From Parking to Café Space

Photograph by the author.



Figure 4-24. Castro Street in 1957

Copyright 1977 by City Mountain View Public Library Photo retrieved from SpaceQuest's Photostream via Flickr.



Figure 4-25. Castro Street in 2007

Photograph by the author.



Figure 4-26. Castro Street: Close Environs

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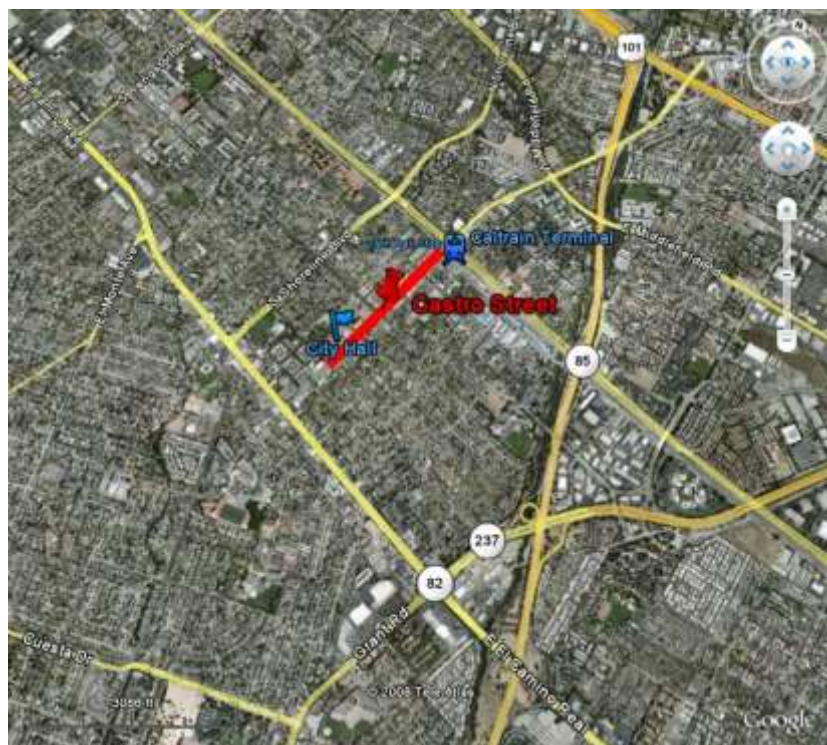


Figure 4-27. Castro Street: Wider Environs

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Characteristics and use.

Castro Street is the traditional main street for the City of Mountain View, as well as an important access route to the Mountain View Transit Center and to such important inter-community and regional highways as the Central Expressway as well as, via Moffett Boulevard, Highway 101. South Shoreline, located parallel to and four blocks from Castro offers drivers a faster car trip between El Camino Real and both the Central Expressway and Highway 101. This relieves the street of some commute traffic pressure. The entire five-block study section of Castro is within easy walking distance of rail and bus services located at the Transit Center.

Castro Street, while best known for its dining opportunities, is also the location for a mix of retail stores and professional offices. The environs of Castro Street comprise predominantly low-density residential development. Notable land uses on the street include an extraordinary variety of ethnic restaurants, the Mountain View Transit Center, and the civic complex comprising the Performing Arts Center, City Hall and the adjacent City of Mountain View Library, along with a Kaiser Permanente medical offices and clinics center. Castro Street is a venue for civic festivals that close the street for motor vehicle traffic, including the Thursday Night Live food and music fair in July and August, the Art and Wine Festival in September, and the Spring Parade in April.⁷²

Average annual daily motor vehicle traffic on Castro Street is 11,900 motor vehicles. I measured 85th percentile motor vehicle travel speed mid-section at 26 mph/42 kph, compared to a speed limit of 25 mph/40 kph. Castro Street is served by Santa Clara Valley Transportation Authority (VTA) buses that operate on the street and by VTA buses and light rail trains, as well as Caltrain commuter rail service, at the downtown Mountain View Transit Center nearby.

Sidewalk widths vary on Castro Street from 20 to 23 feet (6 to 7 meters) on each side along the three blocks closest to the Transit Center to 9 to 11.25 feet (2.7 to 3.4 meters) on the two remaining blocks. Median widths vary from none in the former segment to between 8 and 25 feet (2.4 to 7.6 meters) in the latter. There are no bicycle lanes on Castro Street. Typical motor vehicle travel lane width is 12 feet or 3.7 meters, although there are some segments on the two westerly blocks with

⁷² Information on these street fairs can be retrieved from the Mountain View Downtown Central Business District web site <http://www.mountainviewdowntown.com/events.php>

travel lane widths of up to 15 feet (4.6 meters). Typical left turn lane width is 11 feet/3.4 meters. Figures 28 through 30 illustrate pedestrian space allocation and activity along Castro Street. Figures 31 and 32 illustrate allocation of right-of-way in the westerly reach of the Castro Street study section. Figure 33 shows a typical cross-section on the easterly portion of the street.



Figure 4-28. Pedestrian Space on Castro Street
Photograph by the author.



Figure 4-29. Pedestrians and café patrons on Castro Street
 Photograph by the author.



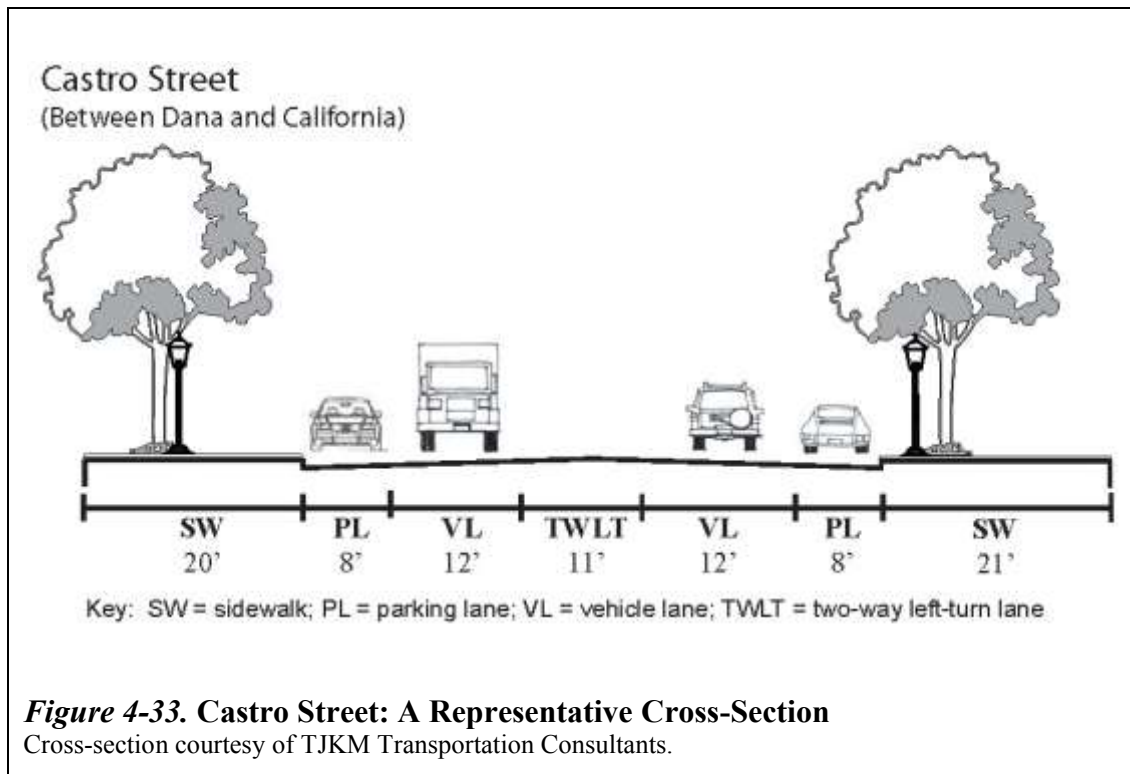
Figure 4-30. A lively Saturday in early November on Castro Street
 Photograph by the author.



Figure 4-31. Castro Street Median Scene, West of Mercy Street
 Photograph by the author.



Figure 4-32. Castro Street Median Scene, West of California Street
 Photograph by the author.



The .25 mile/.4 kilometer buffer of the Castro Street study section had an estimated population of 3,476 and employment of 3,806 in 2007. In density per square mile (1.6 kilometer), this converts to 6,816 residents and 7,463 jobs (26 and 29 per hectare, respectively). The 2008 median household income for the postal code area surrounding this street section, the smallest available geographic area for this information, was \$87,227. This household income was lower than either of the other two streets in the Small City cohort, but still 43% above the statewide median (City-Data, 2010; US Census Bureau, 2009).

Approximately 48% of Castro Street User's Survey respondents reported living in the Old Mountain View neighborhood that surrounds the Castro Street study segment examined in this research. The remainder lived in other Mountain View neighborhoods or in other Bay Area communities. Almost four-fifths of respondents frequently walked to Castro Street. Just over one-half of respondents said that they often accessed the street by driving or riding in someone else's vehicle, about one-fifth by bike, and only 4% by public transport. Not surprisingly, 94% percent of respondents indicated that dining was an important reason for their visits to Castro Street, almost half said the shopping was a major purpose, one-third of respondents

often came to the street for personal or professional services, and two-fifths visited Castro regularly for banking.

As a field researcher, as well as a café patron before and since, I have always found Castro Street to be a stimulating place, socially and visually. I don't think much about the motor vehicle traffic adjacent to the sidewalks since the motor vehicle travel way is comparatively narrow and motor vehicle traffic speeds are not threatening. I find that the sidewalk café scene is a pleasant and lively one. Crossing Castro is comfortable too. I have not enjoyed cycling the street, however, since there is little room between curb side (or the flexible zone between the vehicle through lane and the curb protected on the street side by large planters and used for café tables) and moving motor vehicle traffic.

California Avenue.

California Avenue developed as a business district street after the 1925 annexation of the former town of Mayfield to the City of Palo Alto (Winslow, 1993, p. 33). In the years following the end of World War II, the street boomed as a commercial street — second only to downtown Palo Alto's University Avenue to the north (Winslow, 1993, p. 187). A passenger rail station has been an important part of the street since 1869, when the Southern Pacific Railroad established the Mayfield train depot on Lincoln Avenue, now California Avenue (Winslow, 1993, p. 150).

Characteristics and use.

California Avenue is the funky counterpoint as a main street to Palo Alto's 'tony' and more bustling University Avenue to the north. California Avenue is a destination for diners from the surrounding neighborhoods, as well as from the Stanford Research Park to the southwest. The street retains a mixed-use quality, however, in that it hosts two food markets, a hotel, numerous specialty shops, a yoga studio, and various personal and professional services. California Avenue is car-free to host a popular Farmers Market on Sundays year-round.⁷³

California Avenue includes two motor vehicle travel lanes in each direction and angled parking along most curbsides, but no bicycle lanes. The commercial portion of California Avenue is four blocks long, beginning at El Camino Real and ending at Park Street, just west of the Caltrain tracks and Alma Street. The west end of the street is a dead-end for motor vehicle traffic, but not for pedestrian and

⁷³

Retrieved from <http://www.urbanvillageonline.com/markets/california.php>

bicyclists, who may continue eastward via an undercrossing of both the railroad tracks and Alma Street. California Avenue is linked to both El Camino Real/State Route 82 and Caltrain, regional transportation facilities that connect Palo Alto to San Jose in the south and San Francisco to the north. Figures 34 and 35 present closer in and further out views of the environs of California Avenue.

Average annual daily motor vehicle traffic on the street is 9,700. I recorded the off-peak 85th percentile motor vehicle speed mid-section at 22 mph/35 kph, compared to a speed limit of 25 mph/40/kph. This makes California Avenue the only one of the streets with an 85th percentile motor vehicle speed below the posted speed limit. Both the motor vehicle volume and the motor vehicle speed was the lowest of the six street sections in this research study, not surprisingly since the street dead-ends for motor vehicle traffic. Figures 36 and 37 illustrate these motor vehicle travel and parking lane provisions.

Both VTA and the Stanford University Marguerite shuttle provide public transport bus service along California Avenue. Caltrain operates commuter rail service to the California Avenue station.

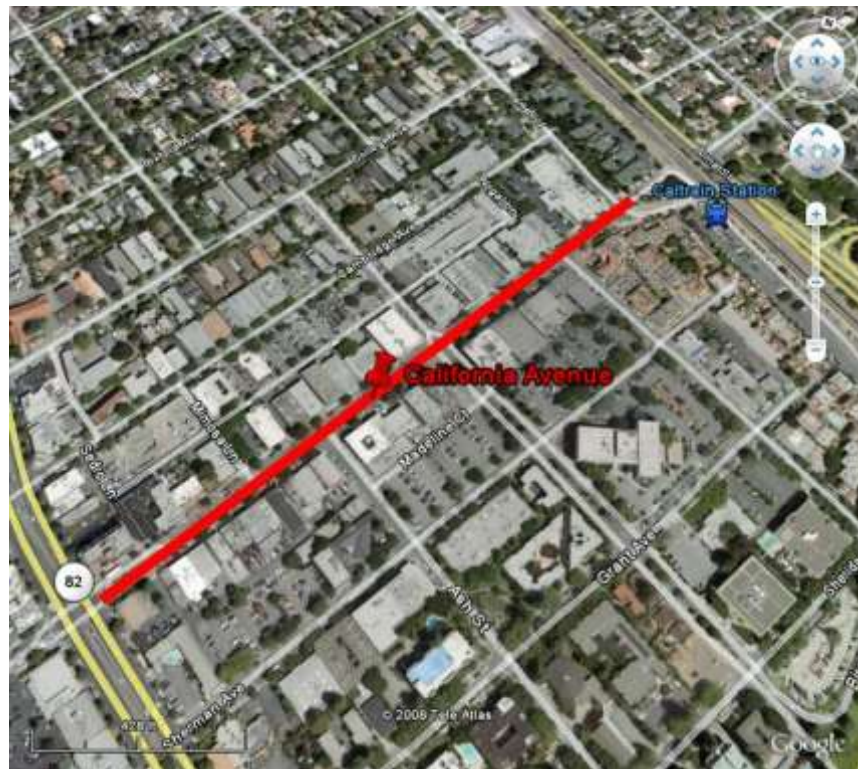


Figure 4-34. California Avenue: Close Environs

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Sidewalk widths on each side of the street are 11 feet/3.4 meters. Typical width for motor vehicle travel lanes is 10 feet/2.7 meters. In a few cases where there is angled parking on only one side, travel lanes widths are somewhat wider. Angled parking lane lines are 11.5 feet/3.5 meters in width from curb to adjoining travel lane line. Figures 38 and 39 illustrate a portion of the right-of-way along California Avenue.

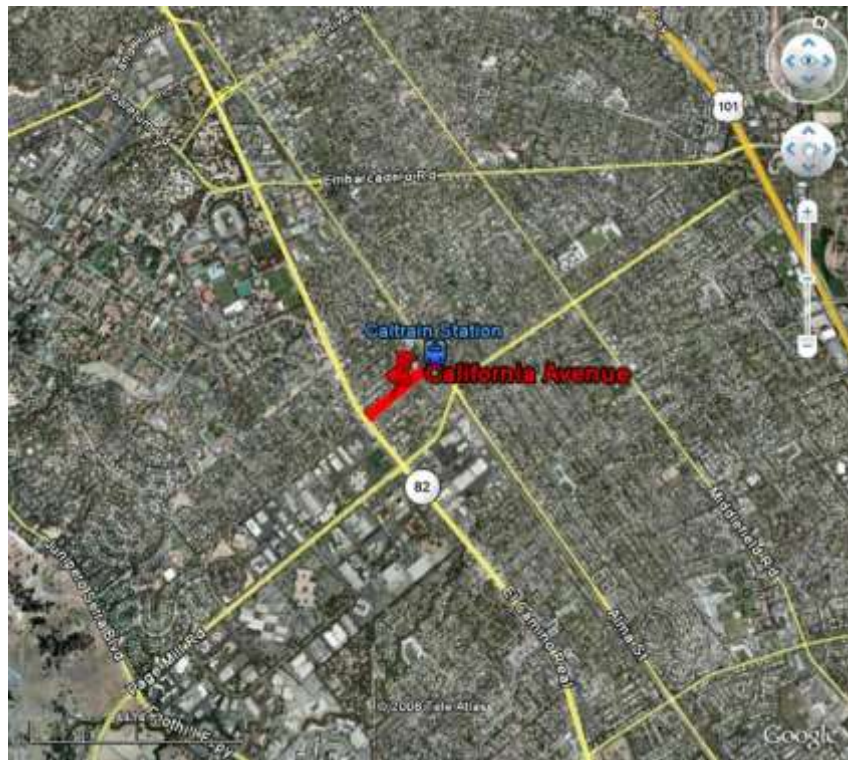


Figure 4-35. California Avenue: Wider Environs
Photograph by the author.



Figure 4-36. California Avenue: Easterly View
 Photograph by the author.



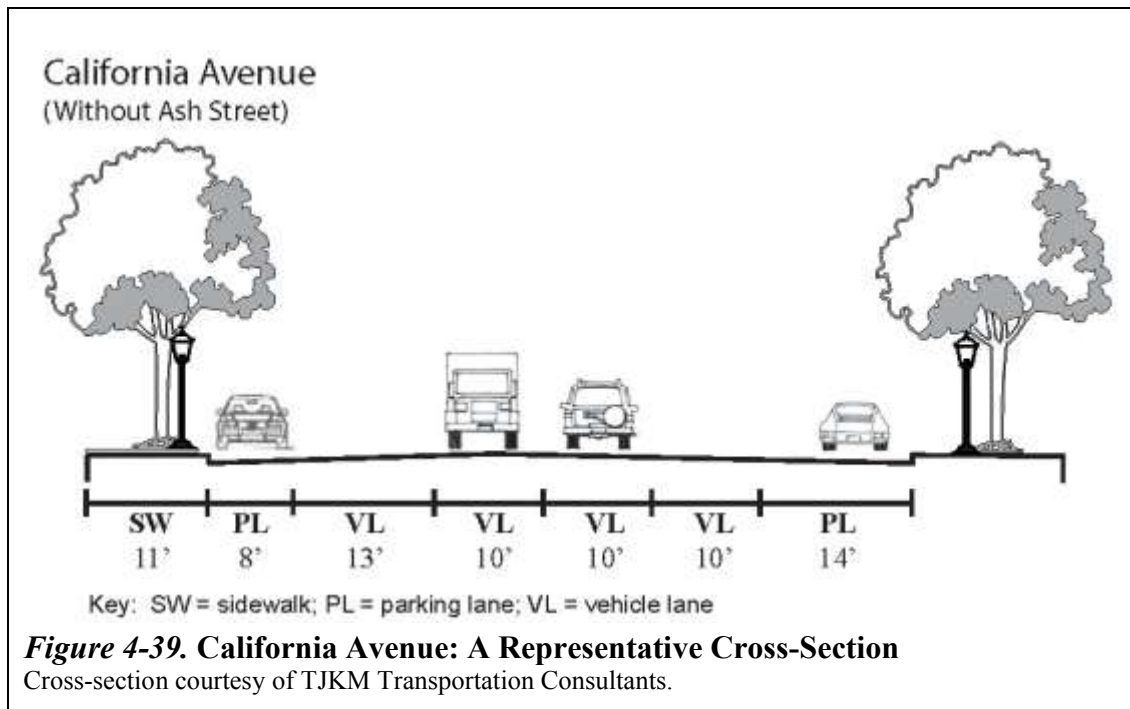
Figure 4-37. California Avenue: Westerly View
 Photograph by the author.

In 2007, an estimated 2,742 people lived and 4,643 worked within a .25 mile/.4 kilometer buffer of California Avenue. In density terms, this means 6,770 residents and 11,464 employees per square mile (11 and 44 per hectare,

respectively). This street had the largest concentration of jobs of the Small City cohort and was second (albeit a distant second) to King Street - The Embarcadero among all six streets in employment density. Median household income in the Evergreen Park, College Park, and Old Palo Alto neighborhoods surrounding the street was \$158,135 in 2008, giving it the highest income level among the six streets in this research effort. Households in these neighborhoods had almost 2.6 times the California median household income (City-Data, 2010; US Census Bureau, 2009).



Figure 4-38. Space apportionment on California Avenue
Photograph by the author.



A total of 44% of California Avenue Street User's Survey respondents claimed residence in either the Evergreen Park neighborhood adjacent to the street or the College Terrace neighborhood across El Camino Real. The remaining respondents resided in other Palo Alto neighborhoods or other communities in the Bay Area. About two-thirds reported that they frequently accessed California Avenue by car. While one-half of the survey respondents often walked to the street, and nearly two-fifths frequently bicycled there, only about 3% came by public transport. As may be expected for a restaurant-rich locale, more than four-fifths of those surveyed said that dining was a frequent trip purpose. About the same proportion often visited for shopping, more than half for personal or professional services, and 30% to bank.

I have visited California Avenue many times over the years, in my professional capacity as Palo Alto's Chief Transportation Official, as a field researcher, as well as a patron of the restaurants, cafes, book stores, and markets on the street. I have always found walking and cycling along California Avenue to be pleasant and comfortable. Nevertheless, I have also always been disconcerted by the contrast between the expansive motor vehicle travel way and the low volume of motor vehicles traversing the street. It is difficult to be on California and not consider the ways in which this excess of street space might be converted to better use.

San Carlos Avenue.

Similar to both Castro Street and California Avenue, San Carlos Avenue is anchored at one end by a Caltrain commuter rail station. Like California Avenue, the section studied in this research is perpendicular to and in close proximity of El Camino Real, State Route 82. El Camino parallels Highway 101 to the east (4.5 miles or 7.25 kilometers by road), the Caltrain commuter rail line close by, and Interstate 280 to the west (.6 miles or about 1 kilometer by road), forming with them the suite of key transport facilities for north-south travel along the San Francisco Peninsula. Figures 40 and 41 reveal up close and further out views of San Carlos Avenue and its environs. Figures 42 and 43 are views of the street looking west and then east. Figure 44 shows the block between Laurel and El Camino Real, which has continuous street frontage and the appearance of a traditional small town main street.

The five-block section of San Carlos Avenue studied here divides into distinct segments. The two most easterly blocks, from El Camino Real to Walnut Street, have angled parking, commercial land use arrayed along the street front right up to the sidewalk and a narrow center median. The middle block between Walnut and Elm has parallel curbside parking and front setbacks between the commercial uses along the street and the sidewalk. The two westerly blocks have parking lanes on each side parallel to the curb, front setbacks, and bicycle lanes in each direction. There is a center median section along a portion of the block between Cedar and Chestnut. The entire five-block section has two motor vehicle travel lanes in each direction.

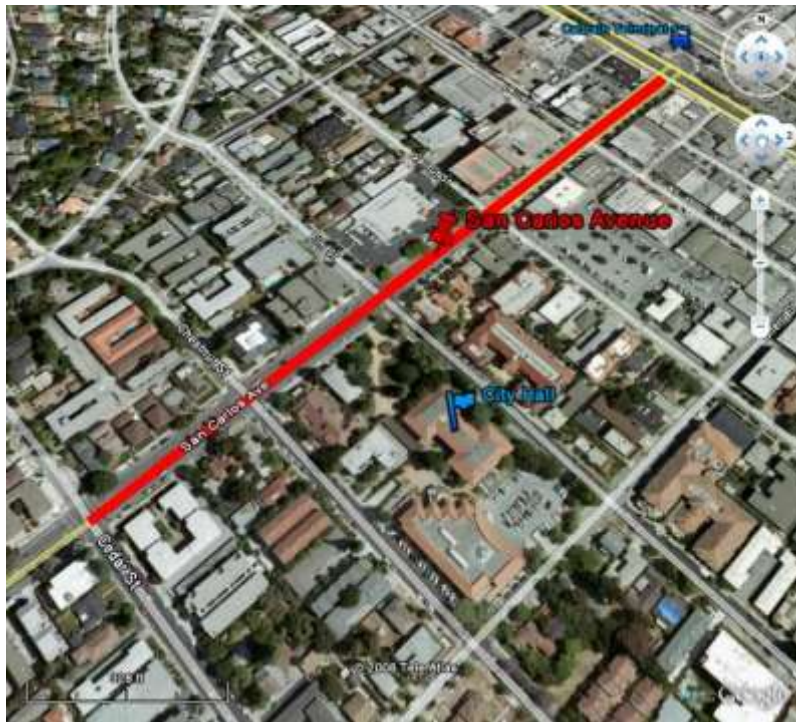


Figure 4-40. San Carlos Avenue: Close Environs
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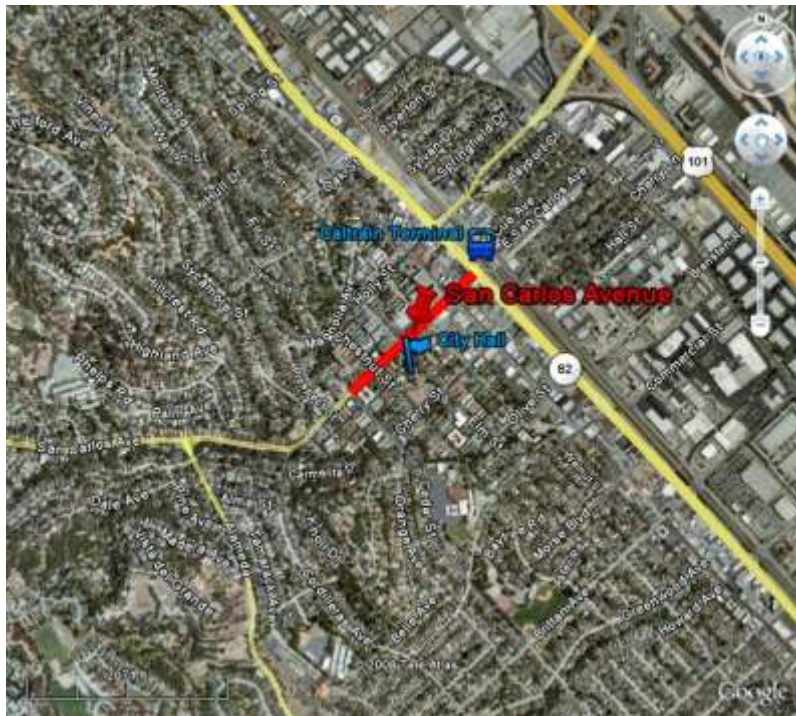


Figure 4-41. San Carlos Avenue: Wider Environs
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Figure 4-42. San Carlos Avenue: Westerly View
Photograph by the author.



Figure 4-43. San Carlos Avenue: Easterly View
Photograph by the author.



Figure 4-44. San Carlos Avenue between Laurel and El Camino Real

Photograph by the author.

Characteristics and use.

San Carlos Avenue is an important commuter route linking the residential districts west and upland from downtown San Carlos to El Camino Real/State Route 82, Caltrain, and (via Holly Street) Highway 101. While Holly Street, which is parallel to San Carlos Avenue one block north, provides an alternative route, it is only three blocks long west of El Camino Real and thus does not provide extensive reach upland into the western residential areas of the city offered by San Carlos Avenue. As a result, San Carlos Avenue remains an important way for drivers who live to the west to access El Camino Real and Highway 101 for trips north to San Francisco, south to San Jose, or to any of the intermediate cities.

The eastern two blocks of San Carlos Avenue are part of the T-shaped pair of traditional Small City downtown streets formed by the linkage of Laurel Street, the city's main commercial street, with San Carlos. San Carlos Avenue, unlike Castro Street and California Avenue, however, is more a traditional main street in embryo than in fact. The entire five-block section studied has two through motor vehicle travel lanes in each direction.

I recorded off-peak 85th percentile mid-section motor vehicle speeds on San Carlos Avenue at 32mph/51.5kph, highest in the Small City street cohort. The speed limit is 30 mph/ 48 kph from Cedar to Elm and 25mph/40kph from Elm to El Camino Real. The quarter-mile distance from each side and either end of the section of San Carlos Avenue in this dissertation research had an estimated population of 3,057 and employment of 1,682 in 2007. The equivalent densities were 7,193 people and 3,958 workers per square mile (28 and 15 per hectare, respectively). Estimated median household income in 2008 for Downtown San Carlos, San Carlos Village, Laureola, McDougall, and Brittan Heights neighborhoods that surround this segment of San Carlos Avenue was \$114,371, the highest among the group of six streets studied and 87% higher than the median income statewide (City-Data, 2010; US Census Bureau, 2009). Average annual daily traffic on San Carlos Avenue between Cedar and El Camino Real is 20,000 motor vehicles, the highest level in the Small City cohort.

Land use on the three easterly blocks comprises restaurants, small shops and stores, as well as professional offices. The two westerly blocks are a mix of civic uses, including a small park and a senior citizen center, along with professional offices, and both multi-family and single-family housing units. The most notable building is the headquarters of the San Mateo County Transit District (Samtrans), located at the corner of Laurel Street and San Carlos Avenue. The San Carlos City Hall and Library, while not situated on San Carlos Avenue, are adjacent to the city park that fronts the street. Both San Carlos Avenue (from El Camino Real to Walnut) and Laurel Street (from San Carlos Avenue to Arroyo) are closed to motor vehicle traffic during the two-day annual San Carlos Art and Wine Festival.⁷⁴

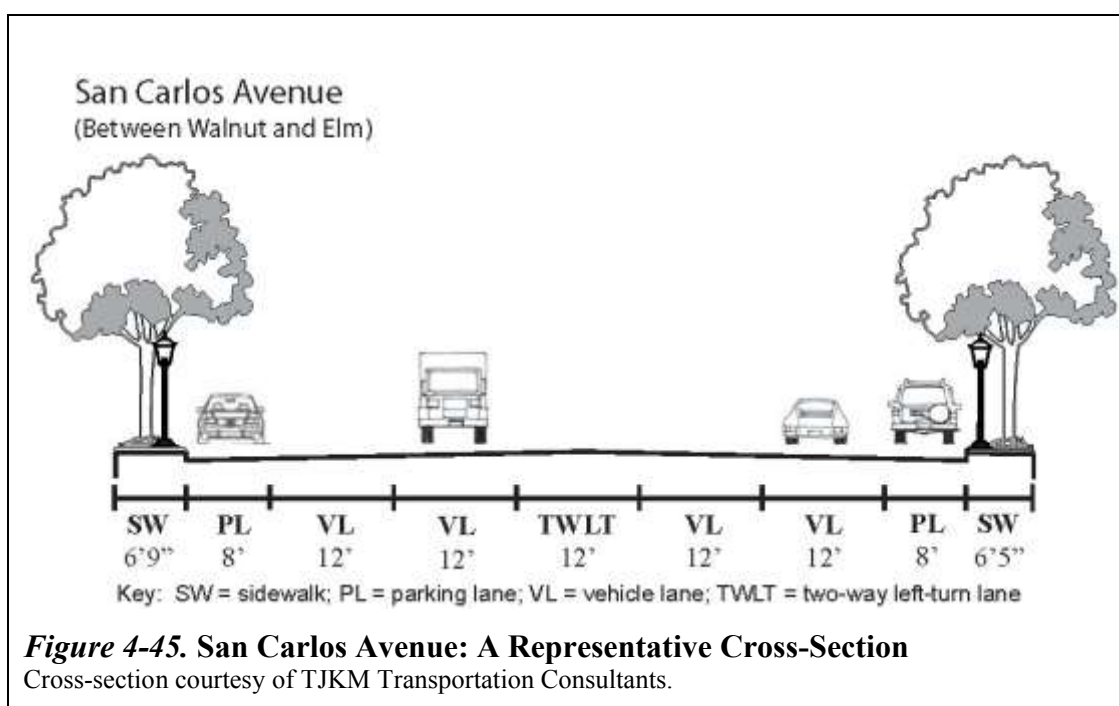
The proposed San Carlos Transit Village project, which is located adjacent to the Caltrain commuter rail station across El Camino Real from San Carlos Avenue, may add a critical mass of new development to the downtown San Carlos environs. The project is comprised of 280 multi-family residential units, 30,000 square feet of commercial space and a new commuter rail station.⁷⁵

⁷⁴ Information about this street fair can be retrieved from the Artsopolis web site:
http://www.artsopolis.com/event/detail/440823143/San_Carlos_Art_and_Wine_Festival_2010

⁷⁵ Information about this project can be retrieved from the City of San Carlos web site:
http://www.cityofsancarlos.org/planning/projects/san_carlos_transit_village/project_overview/project_description.asp

Sidewalks along the two blocks closest to El Camino Real are the widest, ranging from 10.5 to 13.7 feet or 3.2 to 4.2 meters. Sidewalks on the remaining three blocks of this street section vary from 6.4 to 9.2 feet or 2.0 to 2.8 meters, depending on block face and segment. The bike lanes from Cedar to Elm are 5.0 feet or 1.5 meters wide. Typical travel lane width is 10 feet or 3.0 meters for the entire five-block reach. Figure 45 illustrates a cross-section on a portion of San Carlos Avenue.

San Carlos Avenue is served by Samtrans buses both along the street, on intersecting El Camino Real, and at the Caltrain commuter rail station across El Camino Real. The San Carlos Caltrain station offers commuter rail service to San Francisco to the north, San Jose to the south, and points in-between in either direction. The intensity of public transport service, measured in service frequency or transit vehicle stops per day, along and adjacent to San Carlos Avenue, is the lowest in the entire set of six streets researched in this dissertation.



Three-quarters of the San Carlos Street User's Survey respondents lived in San Carlos and the remainder came from elsewhere in Bay Area. About two-thirds of survey respondents frequently accessed the street as a car driver or passenger, about half of the respondents on foot, less than one-quarter bicycled to the street and about one-seventh reached the street by public transport. Most of the latter came by rail. More than two-thirds of respondents frequently dined at a restaurant along the street,

more than one-half often shopped, and over one-fifth visited personal or professional services establishments. Unlike the other two Small City Street User's Survey respondents, however, a significant proportion (almost one-quarter) said that they frequently traveled the street to get somewhere else by road or by rail and 17% reported they frequented San Carlos Avenue for work purposes.

In my field work on San Carlos Avenue and in subsequent visits to it as part of my professional work (a public transportation district at which I have meetings has offices on the street), I often have had the impression of a street that works neither as a livable, traditional main street, nor even as an efficient motor vehicle traffic conduit. I have not felt comfortable crossing the street as a pedestrian because of motor vehicle traffic speeds and the crossing distance from curb to curb. My experience as a cyclist on San Carlos Avenue has also been uncomfortable due to the dropped bicycle lane that forces cyclists into mixed traffic.

Examining the Data

Chapter 5 presents results of research on the activity on and sustainability of each of these six streets. This research was informed by the literature reviewed in Chapter 2. The investigation was also guided by the methods and protocols discussed in Chapter 3. The inquiry took place in context of two sets of streets, three to a set. This context, or anatomy, for each one of the street sections was described in this chapter. Chapter 5 explores how this context influenced the research findings on active, sustainable streets.

CHAPTER FIVE

FINDINGS

Findings from Street Comparisons

Overview.

Chapter 1 to 4 described the research purpose, reviewed the scholarly literature, detailed the research methods applied in this study, and described each of six streets investigated. This chapter presents research results. Chapter 6 explores the meaning and implications of these results, while Chapter 7 answers research questions and discusses directions for future research.

Chapter 5 is comprised of three major sections: Findings from Street Comparisons, Findings for Street Attributes, and A Comprehensive Assessment of Six Streets for Activity, Sustainability. The first consists of results from comparisons within each street cohort as well as across the entire sample of six streets. The second explores relationships between street characteristics and measures of street activity and sustainability. The third returns to the six streets for a comprehensive evaluation.

These research findings emerge from an analysis of data and information obtained in extensive fieldwork and from secondary sources as described in Chapter 3. As discussed previously, I employed a mixed-methods research strategy to evaluate the activity on and sustainability of six street sections in five cities on the San Francisco Peninsula. This endeavor entailed gathering both quantitative and qualitative information on all the streets.

Organization of results.

The research findings in Chapter 5 comprise ten sub-sections:

1. Right-of-way and Street Frontage;
2. Bicycle and Pedestrian Context;
3. Motor Vehicle Operations;
4. Public Transport;
5. Population and Employment;
6. Travel Safety;
7. Stakeholder Assessment;
8. Data Relationships: Association of Street Metrics for Six Streets;
9. Association of Outcome and Influence Variables; and
10. Conclusions.

Right-of-way and Street Frontage summarizes findings on the apportionment of the street right-of-way itself and the abutting properties. Bicycle and Pedestrian Context describes the physical conditions afforded walkers and cyclists. Motor Vehicle Operations comprises data on vehicular travel. Public Transport includes metrics on services, facilities, and usage. Population and Employment discusses data on the number of residents and workers in the environs of each street section. Travel Safety provides detail on crash data for all six street segments. Stakeholder Assessment explores results of street user's and business surveys, visual assessment exercises, and focus group sessions. Data Relationships: Association of Street Metrics shows the relationship between measures of activity across the sample of streets researched and an array of independent or influence variables identified in Chapter 2 as potentially affecting street activity and sustainability. The Association of Outcome and Influence Variables sub-section reports on the correlations between characteristics of streets and their environs with metrics on how streets are used. The Conclusions section presents a comprehensive assessment of the six streets in this research.

As is the case with most comprehensive research studies, some findings meet *a priori* expectations and are intuitive; some do not. Chapter 6 includes a review of what was intuitive and counter-intuitive in the findings contained in this chapter. Thus, any interpretation in Chapter 5 of the research results is a prologue to the more comprehensive discussion of the meaning and implications of these findings presented in Chapter 6. This next chapter will interpret the nature and discern the import for public policy of the findings presented below. The concluding Chapter 7 will return to the research questions posed at the beginning of this work as well as identify the guideposts that these results may provide to future research.

“The Forest and the trees”.

This chapter examines both the forest and the trees. The multidimensional approach requires a fine-grained look at many of the details that comprise a street and its environs. Zooming out to a broader view for the purpose of comparison across streets and the variables that pertain to street activity and sustainability increases understanding of the meaning of these details. Thus, reading this chapter is not unlike looking at streets at different map resolutions in Google Earth, Google Maps, or MapQuest. The task of Chapter 5 is to examine the products of the research and analysis methods described in Chapter 3.

Right-of-way and street frontage.

Street space and street frontage apportionment suggests the priority given to street uses and user groups. The streets examined in this dissertation are studies in contrast as regards these apportionments.

Right-of-way apportionment.

Allocation of street right-of-way varies dramatically among each of the study street sections and their pair of control sections for the Big City and Small City arterials. Motor vehicles on both King Street - The Embarcadero and Castro Street received a smaller percentage of right-of-way (ROW) than on their companion control streets, Lombard Street and The Alameda in the case of King Street - The Embarcadero and California Avenue and San Carlos Avenue in the case of Castro Street. For King Street - The Embarcadero, 43.7% of ROW was reserved as space for public transport, pedestrian, and/or bicycle use, compared to 36% dedicated for motor vehicle use. Motor vehicles on Castro Street got 56.1% of the right-of-way, 27.5% was set aside for pedestrians and natural elements. At the other end of the spectrum, more than three-quarters of street right-of-way on Lombard and San Carlos Avenue, control streets for King Street - The Embarcadero and Castro Street, respectively, was dedicated primarily for the motor vehicle. Figures 1 and 2 display these findings.

While it is true that street design to re-allocate space away from motor vehicle use was an important attribute of each of the two streets selected as exemplary, what is striking is the measurable extent of this reallocation. The sheer magnitude of the contrast in street space use between the test streets and each pair of control streets was not obvious *a priori*. The results for street use, also surprising in magnitude, of this spatial redistribution are explored later on in this chapter.

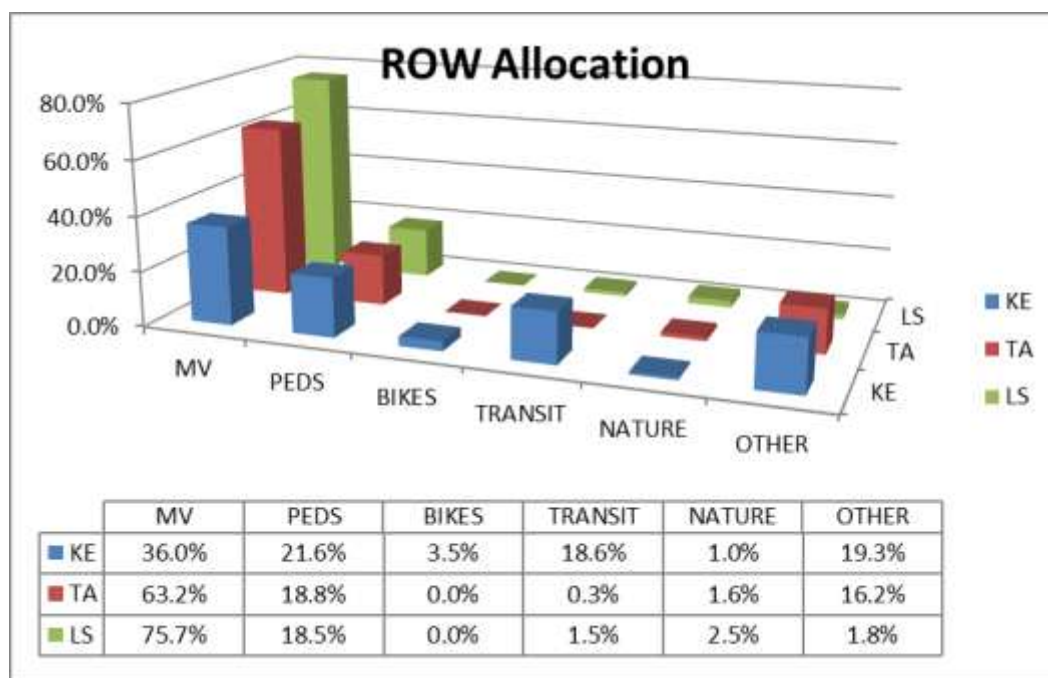


Figure 5-1. Right-of-way (ROW) Allocation: Big City Arterials

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; MV = Motor Vehicle Space; PEDS = Pedestrian space; Nature = Landscape and other permeable surface; and Other = hardscape, ledges, non-permeable median areas, curbing, etc.

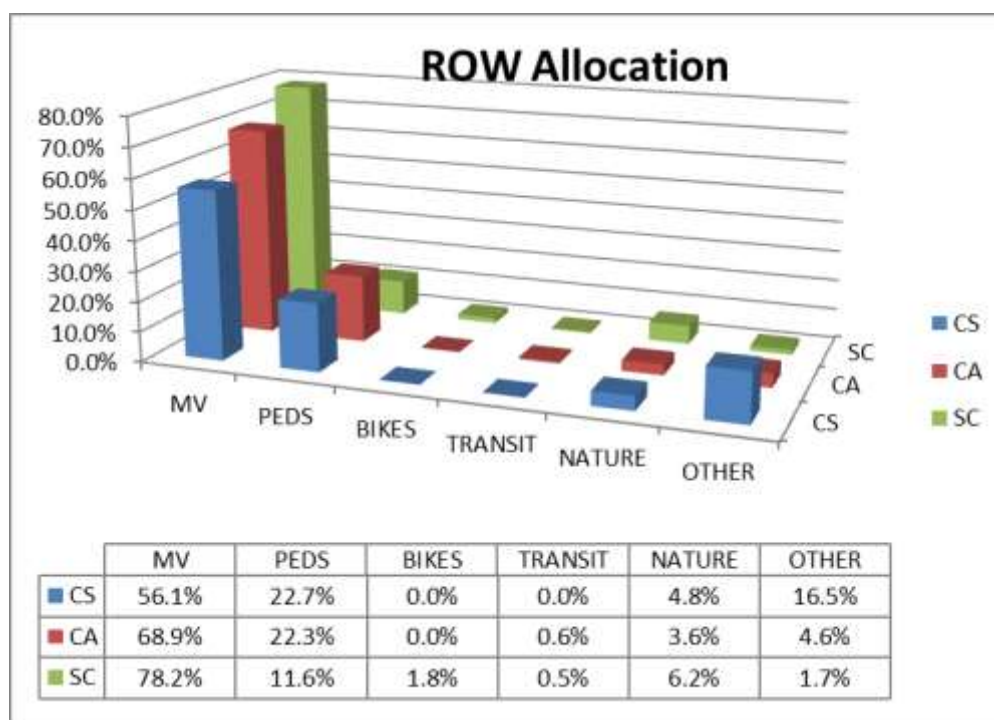
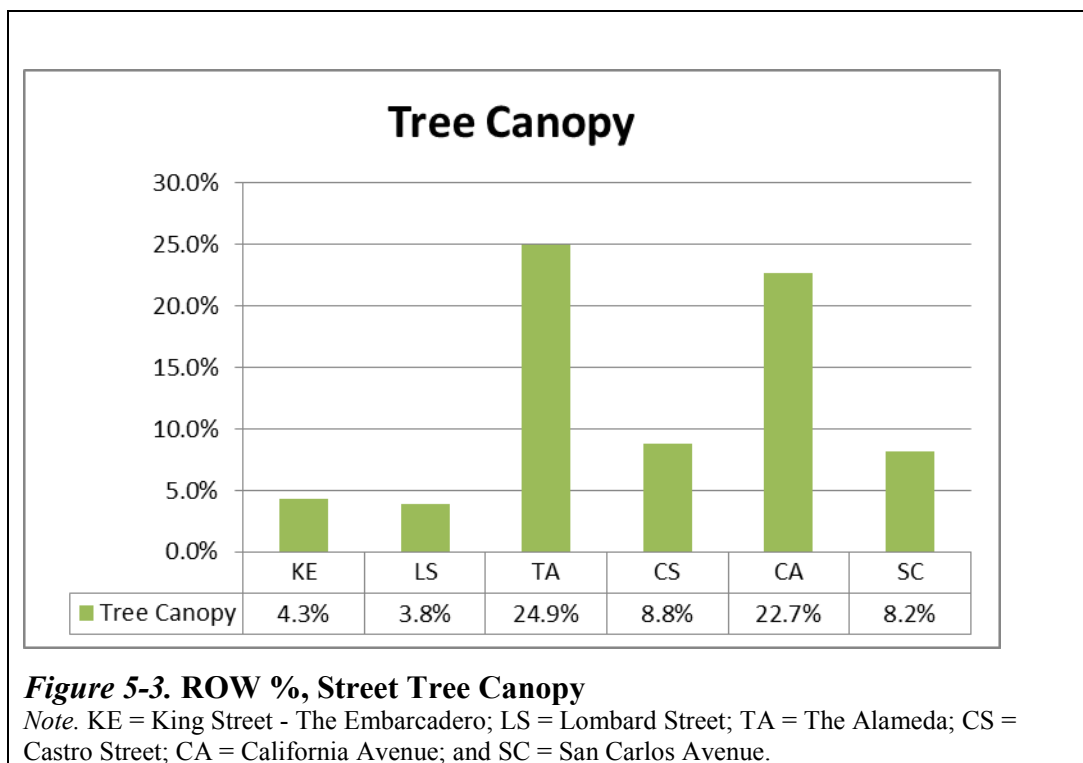


Figure 5-2. Right-of-way (ROW) Allocation: Small City Arterials

Note. CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; MV = Motor Vehicle Space; PEDS = Pedestrian space; Nature = Landscape and other permeable surface; and Other = hardscape, ledges, non-permeable median areas, curbing, etc.

No such pattern emerges with right-of-way in street tree canopy. As shown in Figure 3, the two study or test streets were much less tree-lined than were the streets with the most extensive tree canopy in their respective cohorts.



Street frontage apportionment.

As with tree canopy, the two study streets were not predominant in retail and restaurant frontage. An important caveat with these land use data, however, is that linear feet of street frontage does not measure intensity of use (for example, how many seats in a restaurant or the floor area of a retail shop) *per se*. Interestingly, restaurant and retail frontage for the Small City arterial group predominated over that for the Big City. This predominance in restaurant and retail frontage is in contrast to the generally much higher motor vehicle traffic volumes on the Big City arterial street segments, as a subsequent Figure shows. Figure 4 reveals the linear feet per mile in retail and restaurant use for both the Big City and Small City arterial street cohorts.

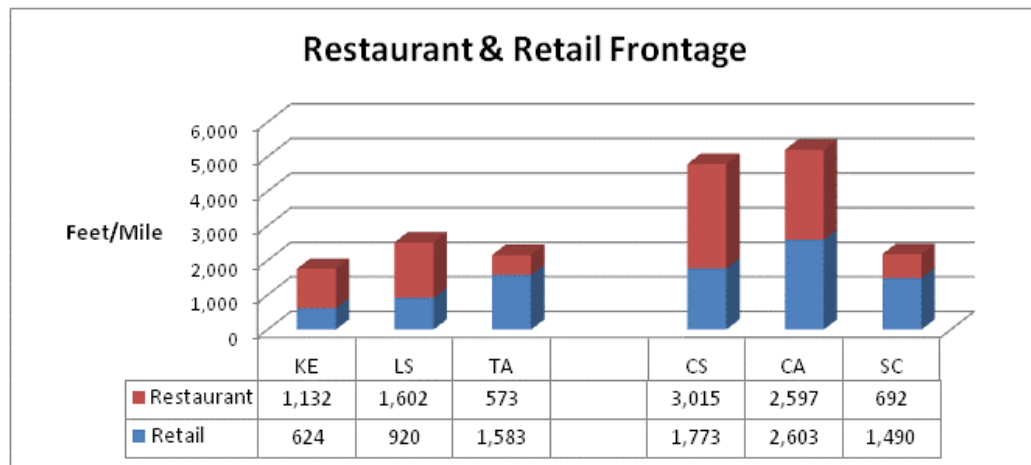


Figure 5-4. Street Frontage in Restaurant & Retail Use

Note. KE = King Street-The Embarcadero; LS = Lombard Street; TA= The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue. Values rounded to nearest whole number.

King Street - The Embarcadero had the greatest amount of discontinuity in the building line (although many of these openings reveal spectacular views of San Francisco Bay) and California Avenue and Castro Street were a close first and second, respectively, in street front continuity. In general, the Small City street segments as a group had greater street front continuity than did Big City street segments. Figure 5 summarizes these data.

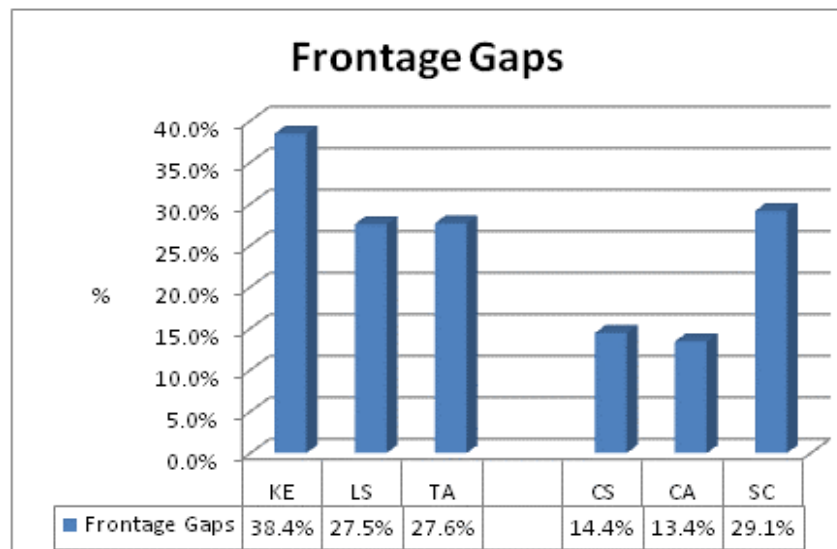
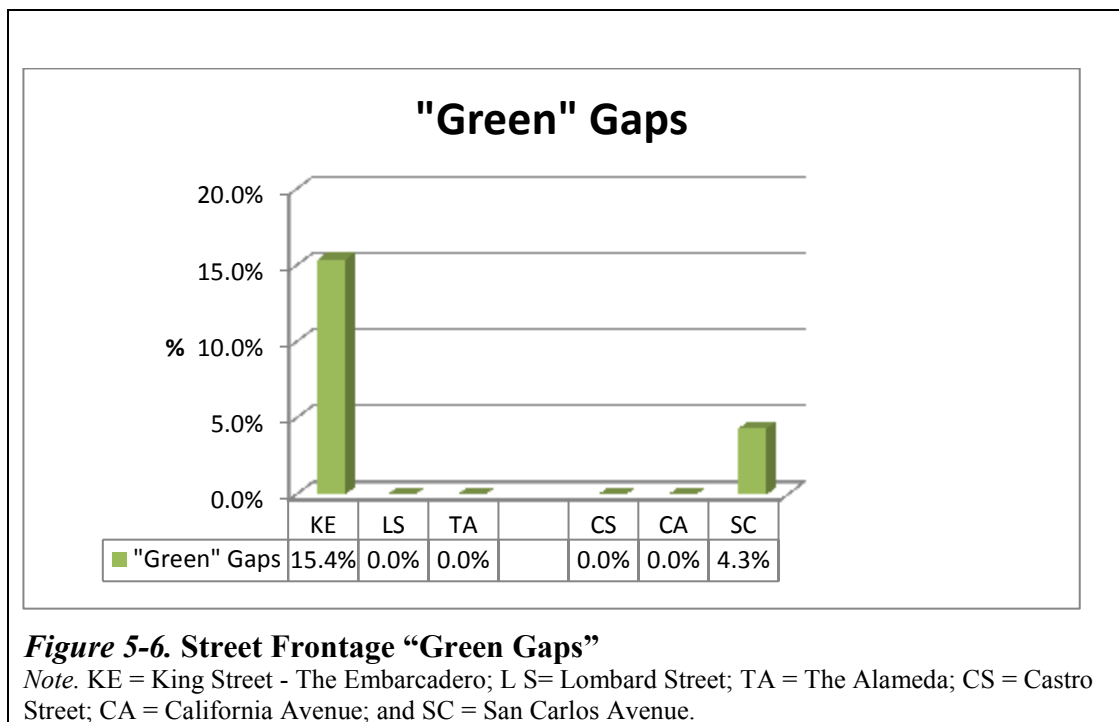


Figure 5-5. Street Frontage Gaps

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

There were polar opposites in each arterial street segment cohort in the proportion of street front devoted to landscaping, lawn, and parkland. In each group, two of the streets had no “green gap” at all. Only King Street - The Embarcadero had a significant amount of street front devoted to nature, most of it being on the east or Bay side of the street in the form of park lawn opening a vista to the Bay itself. The longest piece of San Carlos Avenue’s green frontage stretches along the north side of a park adjacent to San Carlos City Hall and City Library. The rest is in the form of lawns abutting the outer edge of sidewalks on the western reach of the street segment. Figure 6 displays the proportion of street front in green gaps for all six street segments.



The Alameda, an arterial undergoing redevelopment, is the only street segment with an appreciable amount of vacant street frontage. Interestingly, Lombard Street, arguably the ‘grittiest’ of the six streets in this research study, also had the least amount of disused street frontage. The comparatively high levels of motor vehicle traffic on that street sustains auto-oriented land uses that do not generate much pedestrian activity, as will be shown later in this chapter. Figure 7 shows the length of street front on all six streets that consisted of vacant buildings expressed as feet per mile of vacant space.

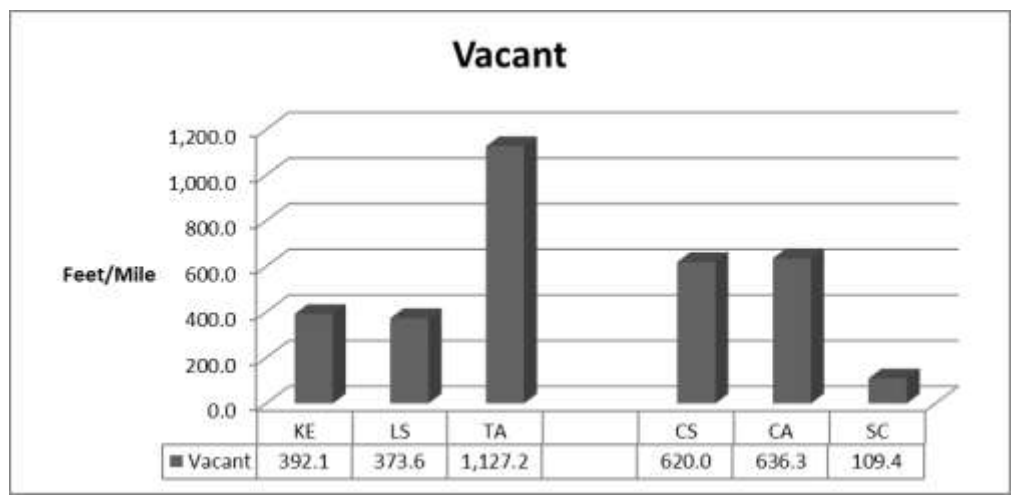


Figure 5-7. Vacant (Disused) Street Frontage

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS= Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Outdoor seating.

Not surprisingly, Castro Street and California Avenue, the arterial streets with the most restaurant frontage per mile, also had the most café chairs per mile. However, while Castro Street only had about 10% more linear feet of street frontage per mile in restaurant use than did California Avenue, it had nearly double the intensity of café seating, .42 restaurant chairs per linear foot of restaurant compared to .23 for California Avenue. Figure 8 reveals the street front café chairs data.

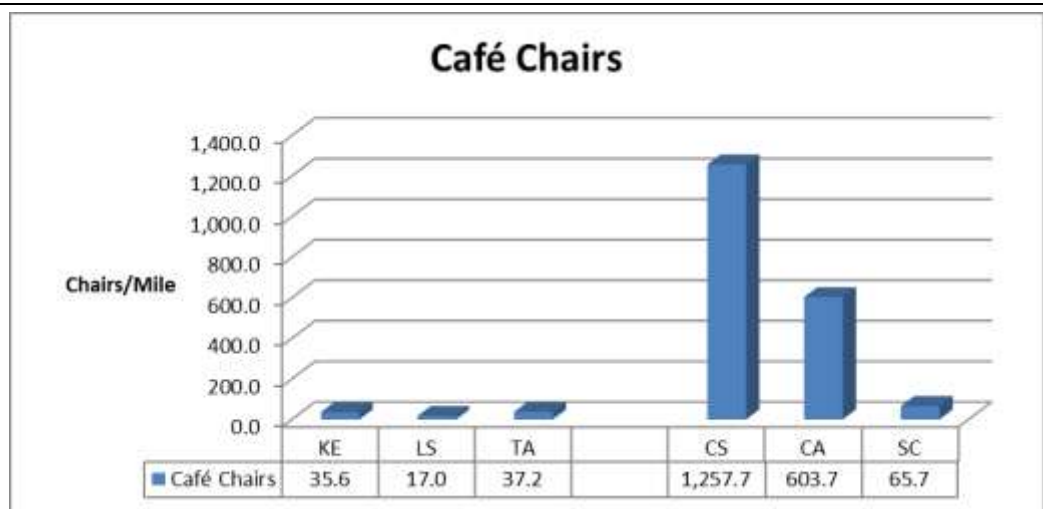


Figure 5-8. Street Front Café Chairs

Note. KE = King Street -The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

The quantity of street front public seating varied dramatically across the six streets with no clear pattern of differentiation between the Big City and Small City arterial street segments. As revealed in Figure 9, California Avenue had by far the highest intensity of public seating, most of which was located away from public transit stops. King Street - The Embarcadero, the only street with higher capacity public transport in the form of light rail, afforded the most seating for public transport passengers.

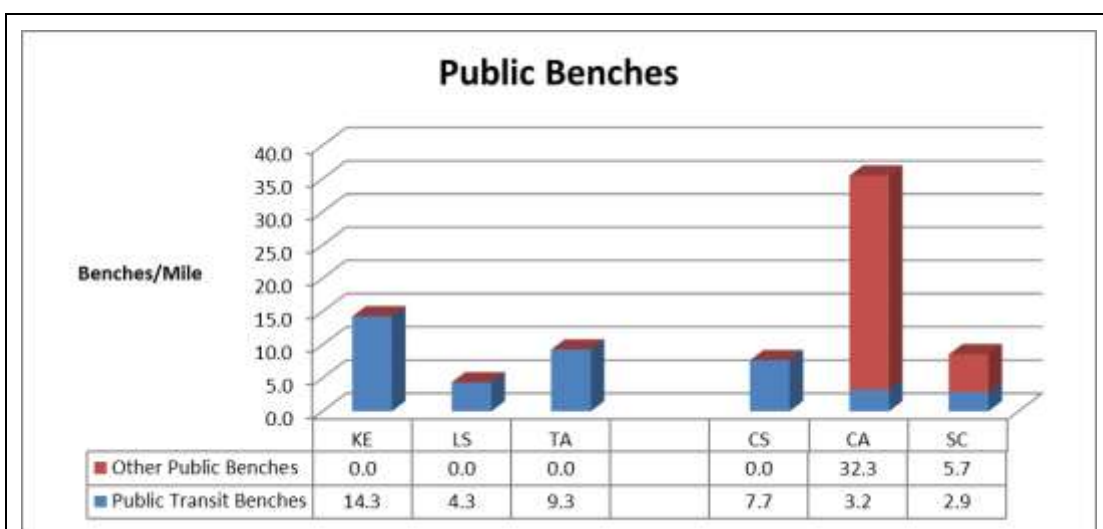


Figure 5-9. Street Front Public Benches

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

I made a subjective assessment of the quantity and quality of informal public seating such as ledges and steps on all six street segments, as reported in Table 1 below. I gave Castro Street, which had extensive informal seating designed into the street front, the only high rating. Notably, however, I assessed each of the study streets as having the best informal public seating in its cohort.

Table 5-1

Subjective Rating of Informal Street Front Seating

Assessment	Street					
	LS	KE	TA	SC	CS	CA
Subjective rating	M	L	L	H	M	L

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; H = high M = medium; and L = low. These ratings reflect the author's own assessment of quantity and quality of informal seating on each street segment.

Windows and doors.

California Avenue, while not the exemplary or study segment in the Small City arterial street cohort, still had the highest number of “active” windows (as defined in Chapter 3) and doors to occupied buildings per mile on the street front along any of the six street segments. Conversely, King Street - The Embarcadero, which is the exemplary or study street segment in the Big City cohort, had the fewest active windows and doors to occupied buildings of any of the six street segments.

In compensation perhaps, as will be seen in a subsequent chart, King Street - The Embarcadero had the highest capacity public transport service along its reach in the form of San Francisco Muni light rail cars with expansive windows, train sets manufactured for Muni with this feature by the Italian firm Breda.⁷⁶ These windows can confer some sense of safety on the street via a similar kind of natural surveillance and transparency afforded by street-front windows. Moreover, in a sense, the four doors (two for each passenger coach) on the two-car light rail train or six doors on the three-car train, also appear to supplement street front doors for entry onto and exit from the street surface. Figures 10 and 11 summarize the windows and doors data, excluding the public transport component on King Street - The Embarcadero.

⁷⁶ Information about these light rail cars can be retrieved from the AnsaldoBreda web site: <http://www.ansaldobreda.com/light-rail-vehicles/san-francisco>

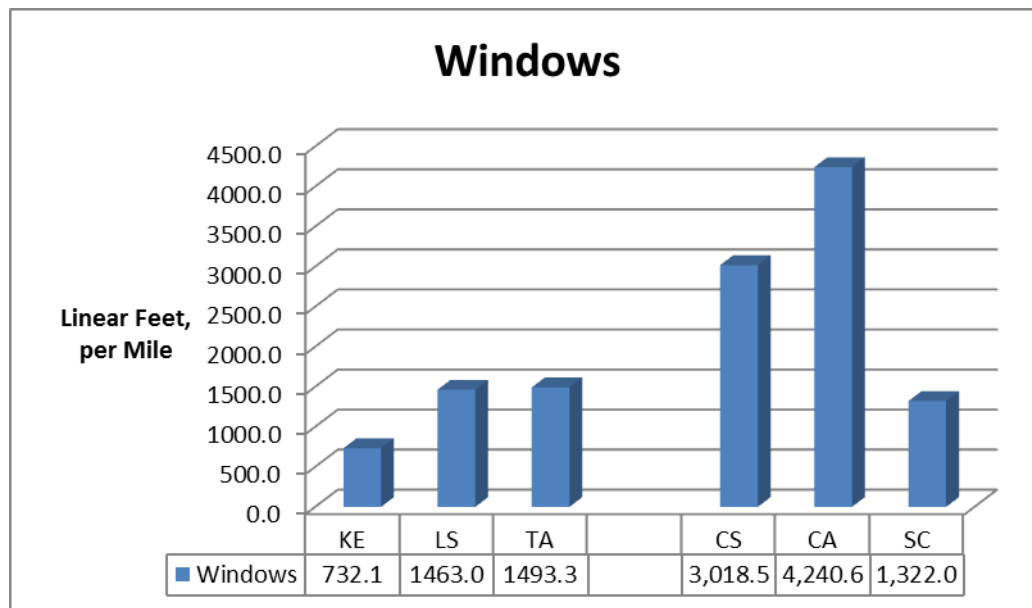


Figure 5-10. Street Front Windows

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

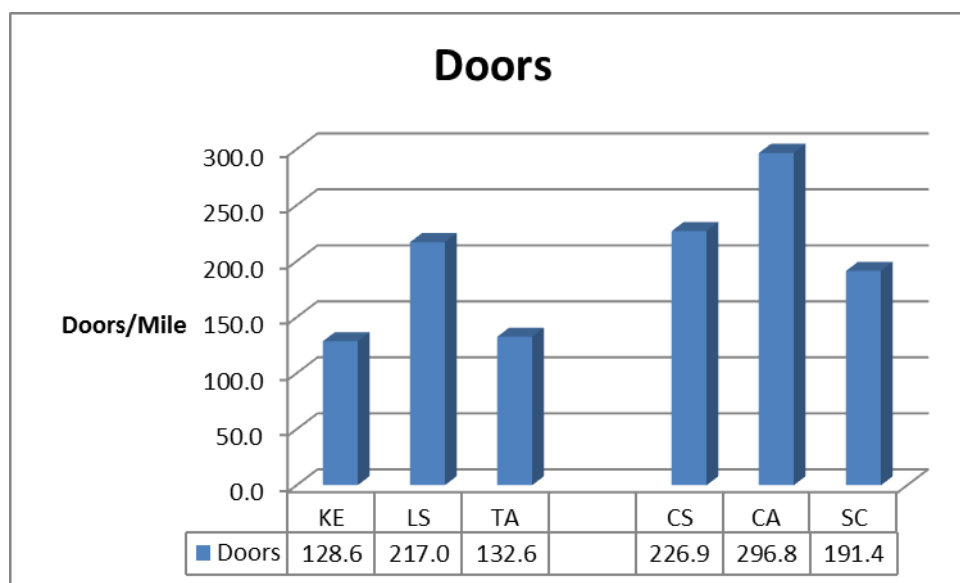


Figure 5-11. Street Front Doors

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Street space allocation on the two exemplary street sections is more favorable to non-motor vehicle uses than is the space allocation on the other street sections. This difference reflects a strategic design focus on the multi-purpose nature of the

street. On the tactical design level, the narrative is mixed. The two study streets are not set apart from the others by streetscape characteristics. There is an exploration of strategic and tactical influences on street activity and sustainability later in this chapter.

Bicycle and pedestrian context.

The extent to which walking and/or cycling occur on any given street depends in part on provisions made for these active travel modes. This context for pedestrians and bicyclists, in turn, may influence how active and sustainable are the streets along which people walk or ride.

Crossings.

Perhaps surprisingly, in the Big City and the Small City street segment cohorts, the exemplary or study street had the fewest total pedestrian crosswalks per mile. On the other hand, King Street - The Embarcadero and Castro Street each had the middle value for crosswalks across the street, which is typically more important for an arterial street, as most of its side streets are narrower than the main street. Similarly, King Street - The Embarcadero and Castro Street had the median values for number of traffic signal controlled crossings per mile in their respective cohorts

In the case of King Street - The Embarcadero, there is little need for crosswalks along the street on the Bay side as the walkway on that side, Herb Caen Way⁷⁷, provides a pedestrian path with few interruptions by cross-streets or driveways. In the case of Castro Street, a calmer traffic situation leads to greater ease and perceived safety for people crossing the street at places without a formal crosswalk. On the other hand, a greater number of formal crossing points may be required on motor vehicle-oriented streets to ensure pedestrian safety. Figures 12 and 13 summarize data on pedestrian crossing provisions for all six street segments.

⁷⁷ Herb Caen was a longtime San Francisco newspaper columnist and *bon vivant* who, ironically, opposed replacing the Embarcadero Freeway with the new boulevard (SF Gate, 1996).

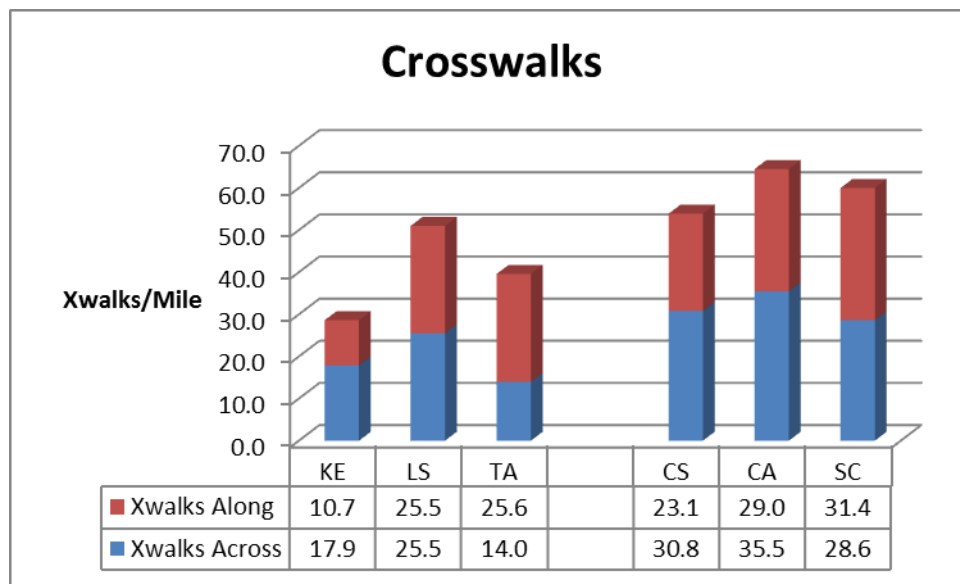


Figure 5-12. Crosswalks Across and Along the Street

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Xwalks = Crosswalks.

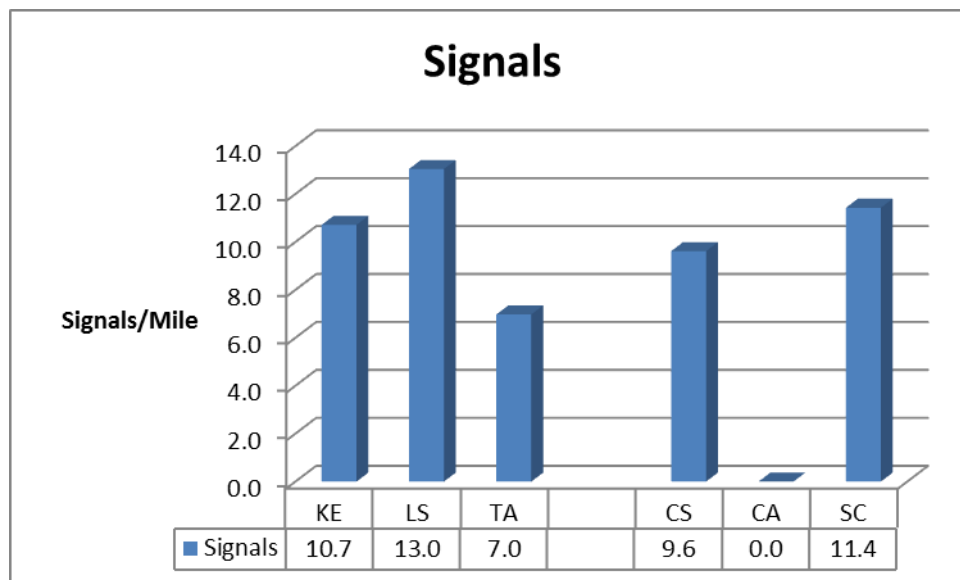
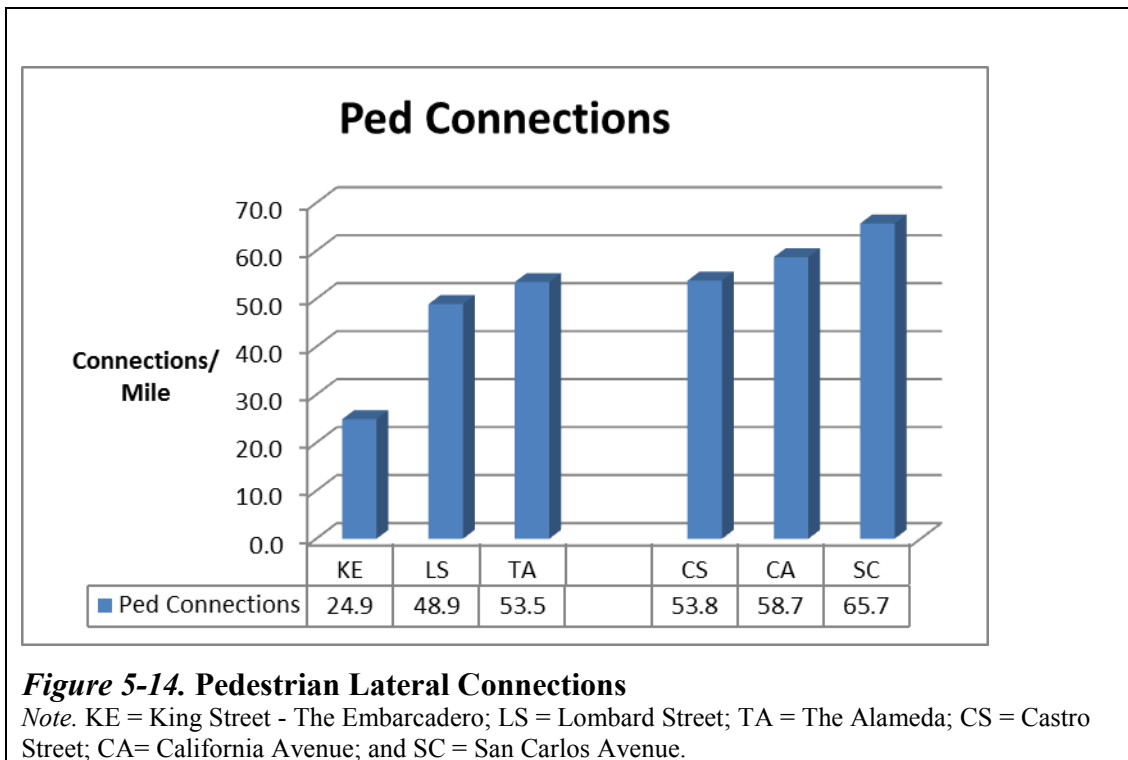


Figure 5-13. Crossing (traffic) Signal Locations on the Street

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Connections, buffers, and driveways.

King Street - The Embarcadero and Castro Street each had the fewest pedestrian lateral connections in their respective street segment cohorts. As defined in Chapter 3, lateral connections are sidewalks, outdoor passageways between buildings, or other spaces dedicated to travel by pedestrians from a street section to parallel streets and other locations. In the case of King Street - The Embarcadero, the paucity of these connections is largely due to the long stretches of Bay side walkway with few driveway crossings and no side streets. Castro Street pedestrian connection density falls in its western reach due to the long block between Mercy and Church Streets. Figure 14 exhibits these findings.



As shown in Figure 15, the number of intersections within a .25-mile (.4 kilometer) buffer on each side and at each end of the six street segments varied substantially. Neighborhoods with largely traditional street grid patterns flank both Lombard Street and Castro Street: The Marina District and Cow Hollow in the case of Lombard Street and Old Mountain View in the case of Castro Street. King Street - The Embarcadero is the newest of the six streets, with most of its western or Bay side uninterrupted by street crossings.

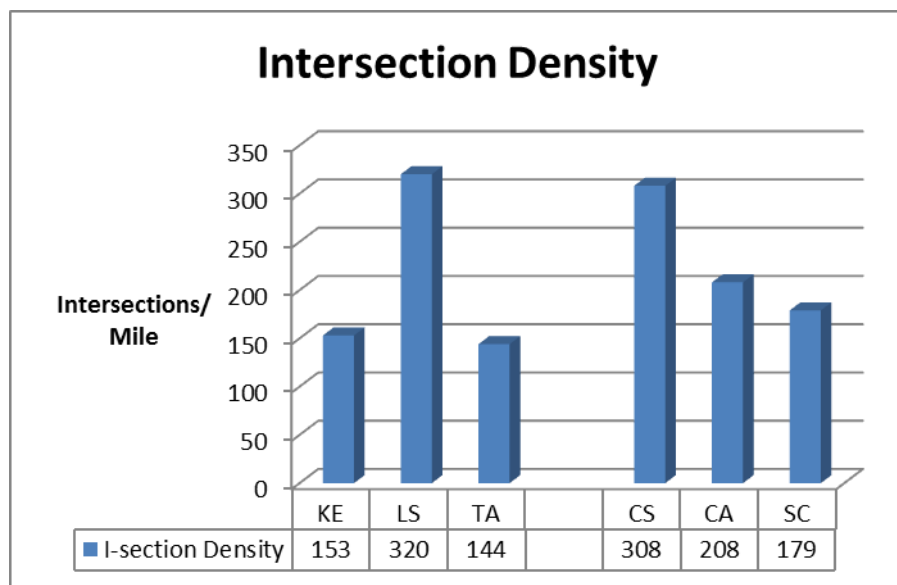


Figure 5-15. Intersection Density

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

King Street - The Embarcadero and Castro Street each had smaller buffer areas separating the pedestrian walkway from moving motor vehicle traffic than the control street segments in their respective street cohorts. Continuous bicycle lanes in each direction and comparatively wide sidewalks on King Street - The Embarcadero mitigate the lack of pedestrian buffer area. On Castro Street, mid-block and intersection bulb-outs (sidewalk extensions at crosswalks), provision of only one through motor vehicle lane in each direction, and comparatively slow motor vehicle speeds also reduce the effect of less curbside parking and other at-grade street buffers between cars and walkers. Figure 16 exhibits the data on proportion of street with pedestrian buffer area.

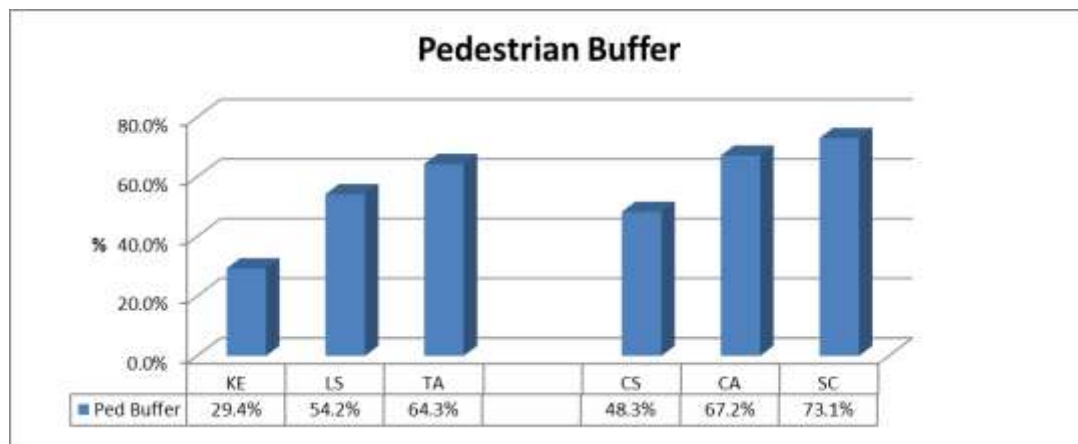


Figure 5-16. Proportion of Curbside with Buffer for Pedestrians

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Ped = Pedestrian.

In contrast, King Street - The Embarcadero and Castro Street each have strikingly fewer commercial driveway interruptions along their study area reach than do the pair of control street segments in each street cohort. This means that there is less exposure to entering and exiting motor vehicles for pedestrians and bicyclists. Figure 17 shows these results.

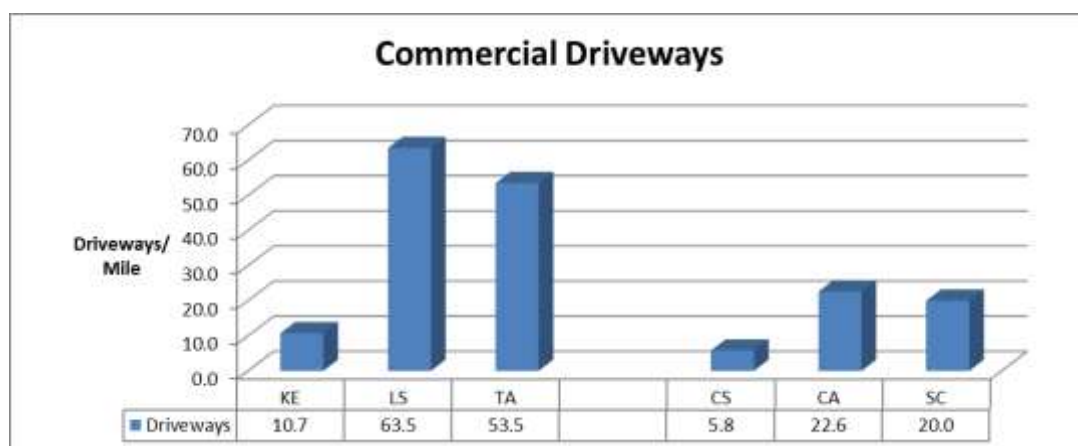
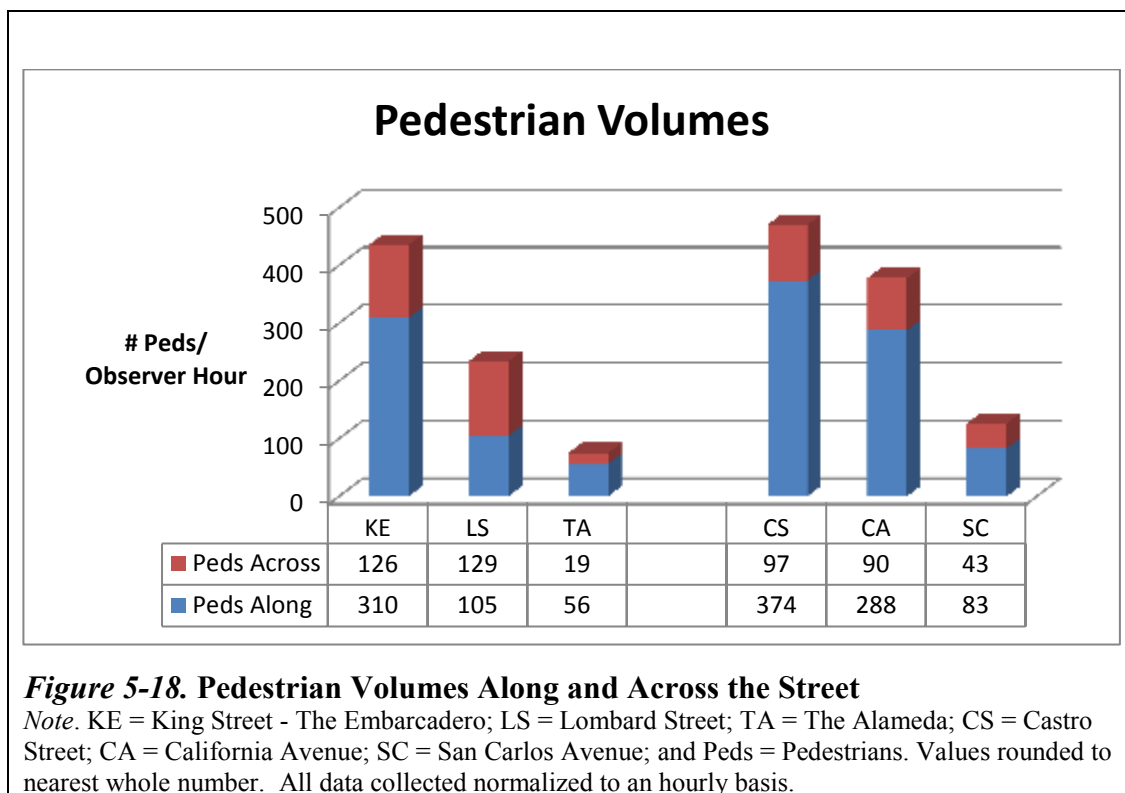


Figure 5-17. Commercial Driveways on Streets

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Pedestrian travel.

There is a consistent pattern of pedestrian travel activity within each cohort of street segments. The exemplary study or test street in both the Big City and Small City groups had the highest total number of pedestrians traveling along and across the street. King Street - The Embarcadero and Castro Street had first and second largest number of walkers. Only California Avenue, the street segment with both the lowest motor vehicle traffic volume and the lowest motor vehicle speeds of the six streets, had a comparable level of pedestrian traffic, as summarized in Figure 18.



Stationary pedestrians.

As shown in Figure 19, Castro Street and California Avenue, the street segments with the most restaurants, also had the most pedestrians sitting and highest total number of pedestrians sitting or standing. King Street - The Embarcadero, the only street segment with light rail service along its reach, had the greatest number of pedestrians standing, many of them doing so at one of its two light rail stops.

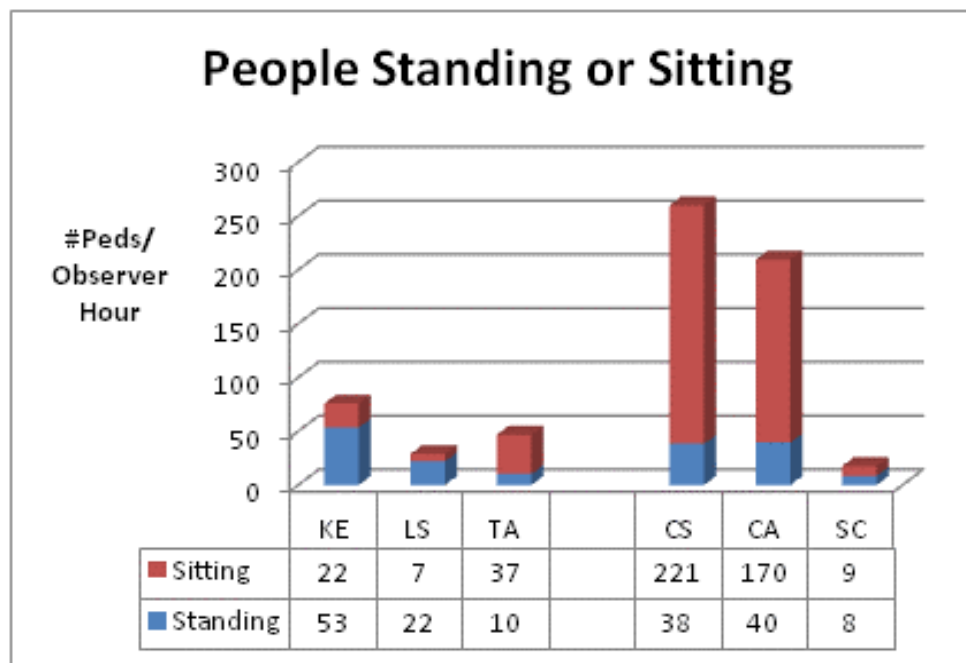


Figure 5-19. People Standing and Sitting Along the Street

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Peds = Pedestrians. Values rounded to nearest whole number. All data collected normalized to an hourly basis.

Pedestrian presence.

The exemplary study street segment in each cohort had the greatest pedestrian presence, measured by total number of walkers, as well as people sitting or standing along the street. The two streets with the most restaurants, Castro Street and California Avenue, also had the greatest pedestrian presence in the entire sample of six street sections, as exhibited in Figure 20.

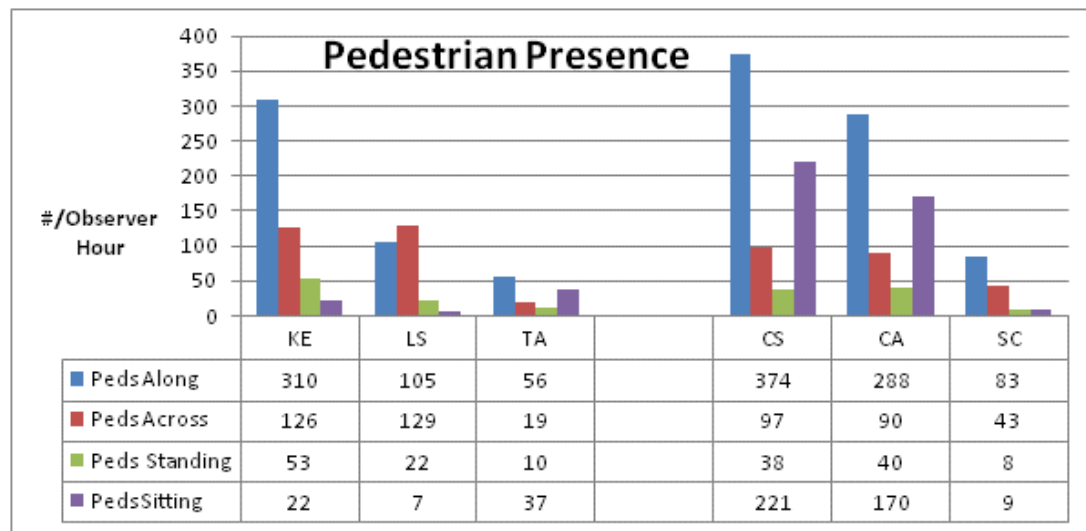


Figure 5-20. Pedestrian Presence: Number of Pedestrians Walking, Sitting, or Standing Along the Street

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Peds = Pedestrians. Values rounded to nearest whole number. All data collected normalized to an hourly basis.

Pedestrian interactions.

The number of pedestrian interactions paralleled the number of people participating in the interactions. Additionally, the Small City streets as a group had more of both pedestrian interactions and people involved in them than did the cohort of Big City streets. However, King Street - The Embarcadero and Castro Street, the two study or test street sections, each led their two respective control street sections in both data sets. Figure 21 displays these data.

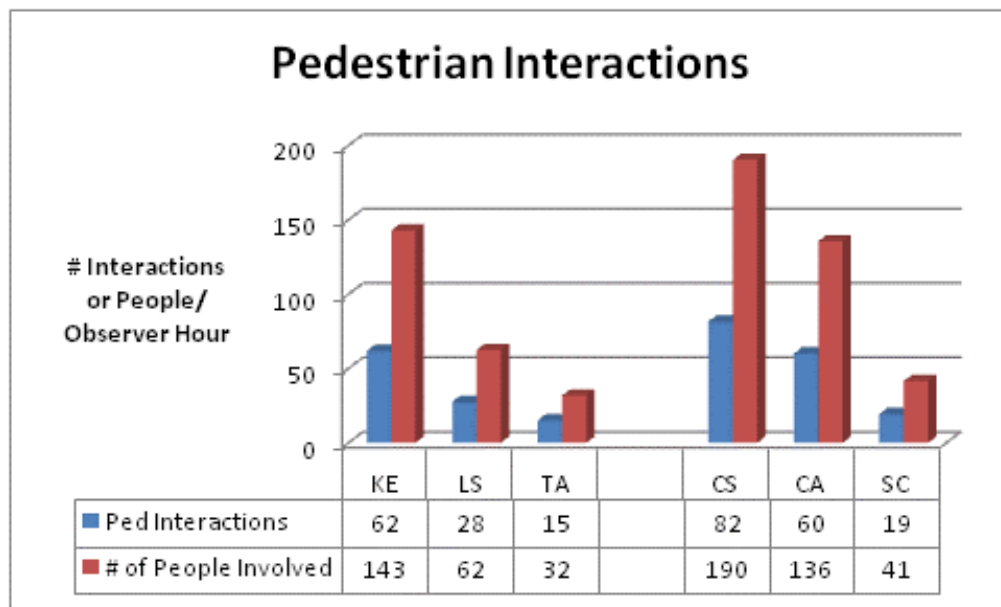


Figure 5-21. Pedestrian Interactions and Number of People Participating

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Ped = Pedestrian. Values rounded to nearest whole number. All data collected normalized to an hourly basis.

Bicycle storage.

California Avenue, a low-traffic-volume street with a direct connection to bicycle-friendly Caltrain commuter rail service, as well as to a bicycle-pedestrian undercrossing of both the Caltrain line and Alma Street immediately to the east of Caltrain, had by far the highest number of bicycle storage racks of the six street segments. Among the three Big City street segments, King Street - The Embarcadero, which had the most extensive bicycle lanes among the six street segments and a direct connection to bicycle-friendly Caltrain, had the most bicycle racks. Figure 22 summarizes these findings.

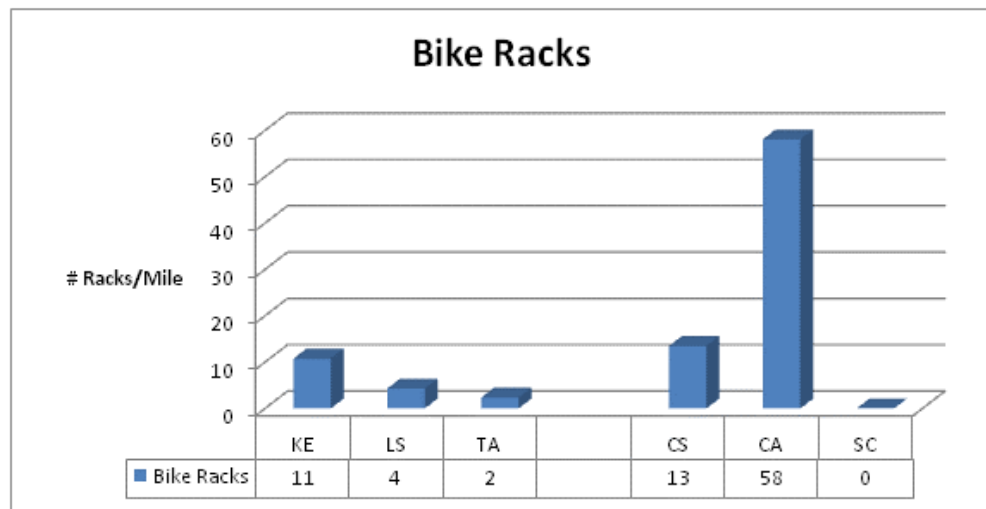


Figure 5-22. Bicycle Racks

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue. Values rounded to nearest whole number.

Bicycle Activity.

Big City cohort bicycle volumes were highest on the exemplary study street, King Street - The Embarcadero. California Avenue was the busiest for cycling of the Small City group. King Street - The Embarcadero had the only continuous bicycle lanes in each direction of the six street segments in this dissertation research. California Avenue had a low motor vehicle traffic volume and a slow vehicle speed environment, with both a bicycle/pedestrian undercrossing and a commuter rail station at one end of its reach. Despite having cycle lanes along half its length, the San Carlos Avenue street segment had a lower bicycle travel volume than any other street. The low bicycle volume on San Carlos may be partly due to the discontinuous bicycle lanes, as well as the comparatively high motor vehicle speeds on the street. Figure 23 displays comparative total bicycle activity on the six streets.

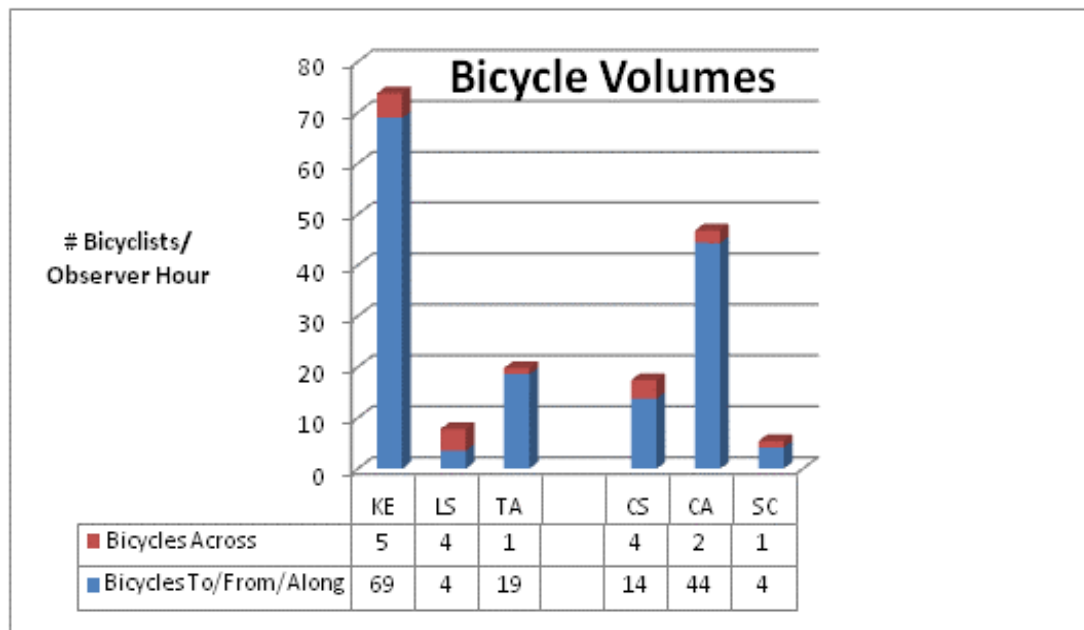


Figure 5-23. Bicycle Volumes Too/From/Along and Across the Street

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue. Values rounded to nearest whole number. All data collected normalized to an hourly basis.

Non-motorized modes activity.

Total bicycle and pedestrian volumes mirror the results for total number of pedestrians with the exemplary study streets leading each cohort. As with the pedestrian totals, only California Avenue compares to King Street - The Embarcadero and Castro Street for total number of pedestrians and bicyclists moving along or across the street. Figure 24 shows these comparisons.

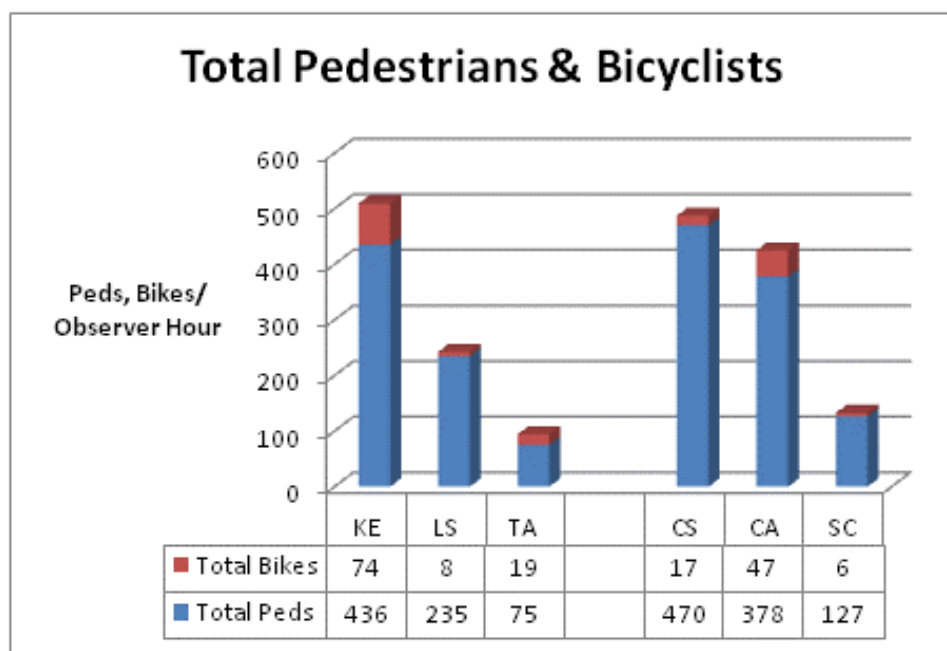


Figure 5-24. Total Pedestrian and Bicycle Volumes on the Street

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Peds = Pedestrians. Values rounded to nearest whole number; all data collected normalized to an hourly basis.

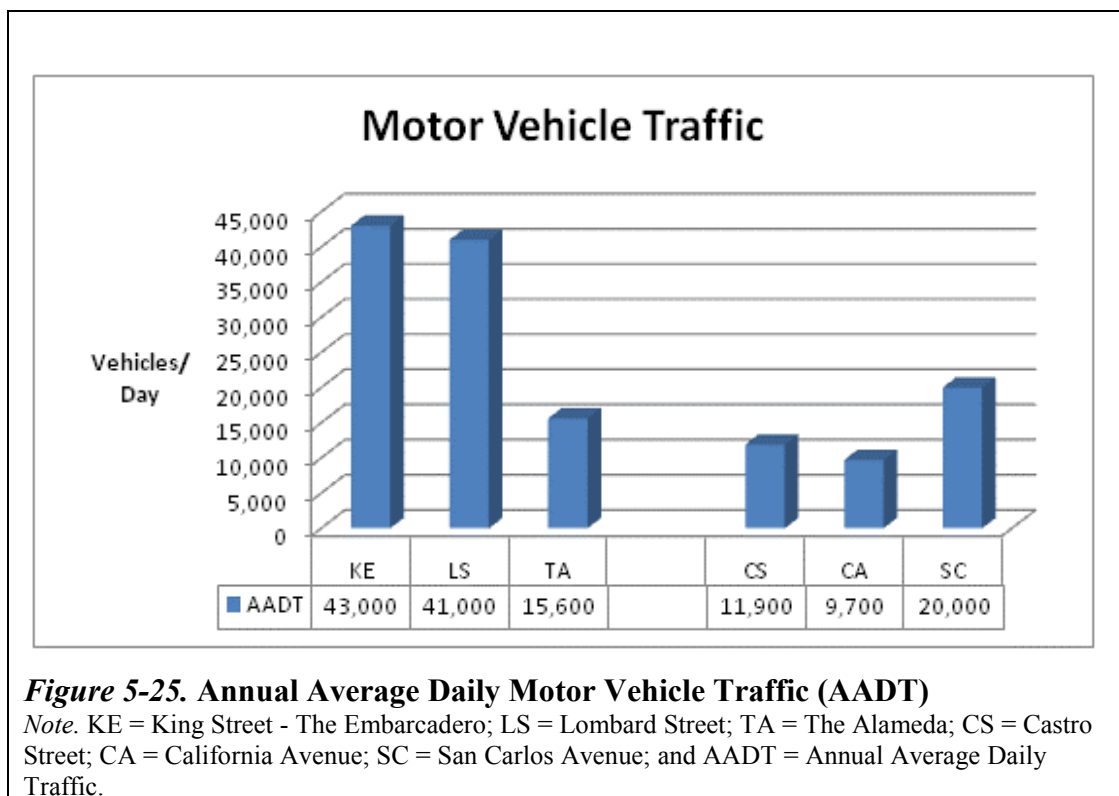
Motor vehicle operations.

Since the early twentieth century, city streets have been re-shaped to make way for motor vehicles (McShane, 1994). The extent of this accommodation to automobiles and trucks influences the appearance and function of streets along with the impact of streets on communities.

Motor vehicle traffic.

While King Street - The Embarcadero had the most motor vehicle traffic among the Big City arterial streets, Castro Street had the median value for traffic among the Small City arterial streets. Motor vehicle traffic volumes on The Alameda are lower than they would otherwise be because of parallel arterial streets that also serve downtown San Jose commuters, as well as providing more direct freeway access for commuters to downtown. In addition, as shown earlier in Figure 7, The Alameda had the highest building vacancy rate of the six streets in this research study. Consequently, there were fewer destinations on the street for motor vehicle traffic. California Avenue motor vehicle traffic is mitigated by the circumstances of its being a dead-end street for through motor vehicle (but not for bicycle and

pedestrian) traffic. As may be expected (and is summarized in Figure 25), the cohort of Big City arterial streets generally had higher levels of daily motor vehicle traffic than the Small City group.



Truck traffic varies across the six street segments. Castro Street, with extensive provision for truck access behind stores and restaurants, had the lowest proportion of trucks in the overall motor vehicle flow. King Street – The Embarcadero, with a direct freeway connection to and from downtown San Francisco and limited provision for truck loading on side streets, had the highest proportion of trucks in its daily traffic stream. California Avenue’s comparatively high percentage of truck traffic may also be an anomaly attributable to a low base daily traffic volume and, as I observed in the field research, ample street space for truck loading. Figure 26 provides additional detail on truck traffic percentages across the sample of street segments. In each case, the proportion of truck traffic in the vehicle stream is less than 2.0%. Nevertheless, the proportionate impact of trucks on human amenity is almost certainly higher, in the same way that trucks do disproportionately high physical damage to road surfaces along which they operate (U.S. DOT, 2000).

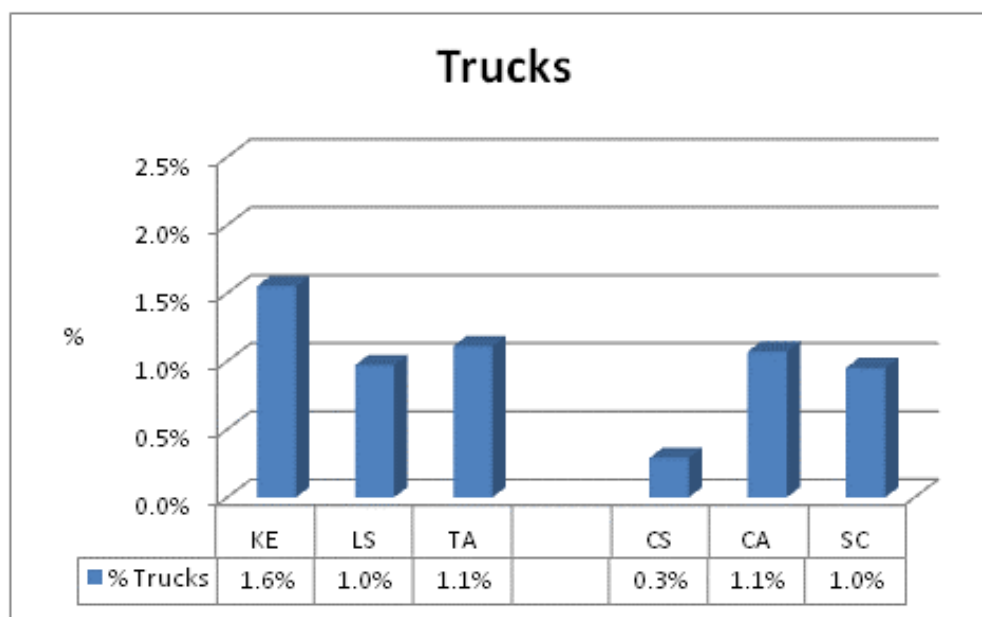


Figure 5-26. Truck Traffic Proportion

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Motor vehicle speeds.

The group of larger city arterial street segments also registered higher 85th percentile motor vehicle speeds. As defined in Chapter 3, this is the speed at or below which 85% of motor vehicles are traveling. King Street - The Embarcadero and Lombard Street each function as surface street extensions of urban freeways, hence serve many through trips. In addition, The Alameda has comparatively low traffic volumes for its cross-section of four travel lanes, allowing plenty of street space for through traffic to use for expedited travel en route to and from downtown San Jose and other destinations. In contrast, dead-end California Avenue has reduced speeds since it does not cater in any way to through motor vehicle traffic. Figure 27 summarizes the data on vehicle speeds.

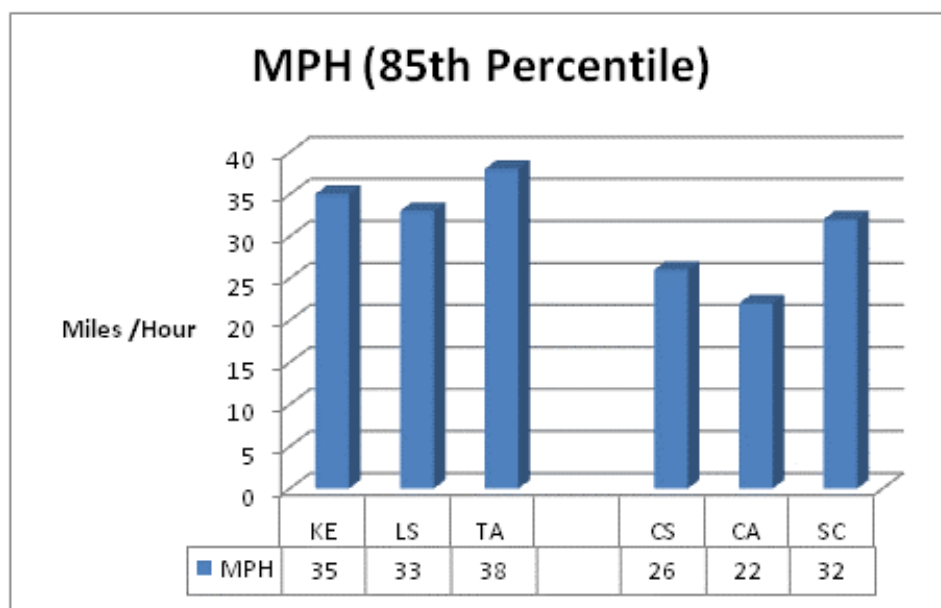


Figure 5-27. 85th Percentile motor vehicle speeds: miles per hour

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and MPH = miles per hour.

Motor vehicle occupancy.

There are only minor variations in the vehicle occupancy rate (VOR) of cars and light trucks across the six street segments. Castro Street's higher VOR may reflect the density of restaurants on the street and the often social rather than solitary nature of dining in that environment. It is likely that the VOR on Castro and California, the two most restaurant-intensive streets in this research study, is even higher at peak lunch and dinner hours, which were not sampled for vehicle occupancy in this research design. Lombard Street's slightly higher VOR than the other two streets in its cohort may be influenced in part by the toll required of cars using the nearby Golden Gate Bridge, then exiting onto Lombard for trips into and beyond San Francisco. As these bridge tolls are per vehicle, not per person, toll costs per person fall as vehicle occupancy rises, creating an incentive to share the ride.

Vehicle occupancy rates sampled were comparatively low. By way of contrast, VOR measured in the 2001 US National Household Travel Survey was 1.63 for all trip purposes and 1.14 for trips to and from work (Hu & Reyscher, 2004). It is likely that the sampling times chosen in this dissertation research resulted in under representation of shopping, social and recreational, and other trip purposes associated with higher vehicle occupancies during evening hours and weekends when vehicle

occupancy rates are typically higher⁷⁸. Figure 28 shows the differences in VOR across the street segments.

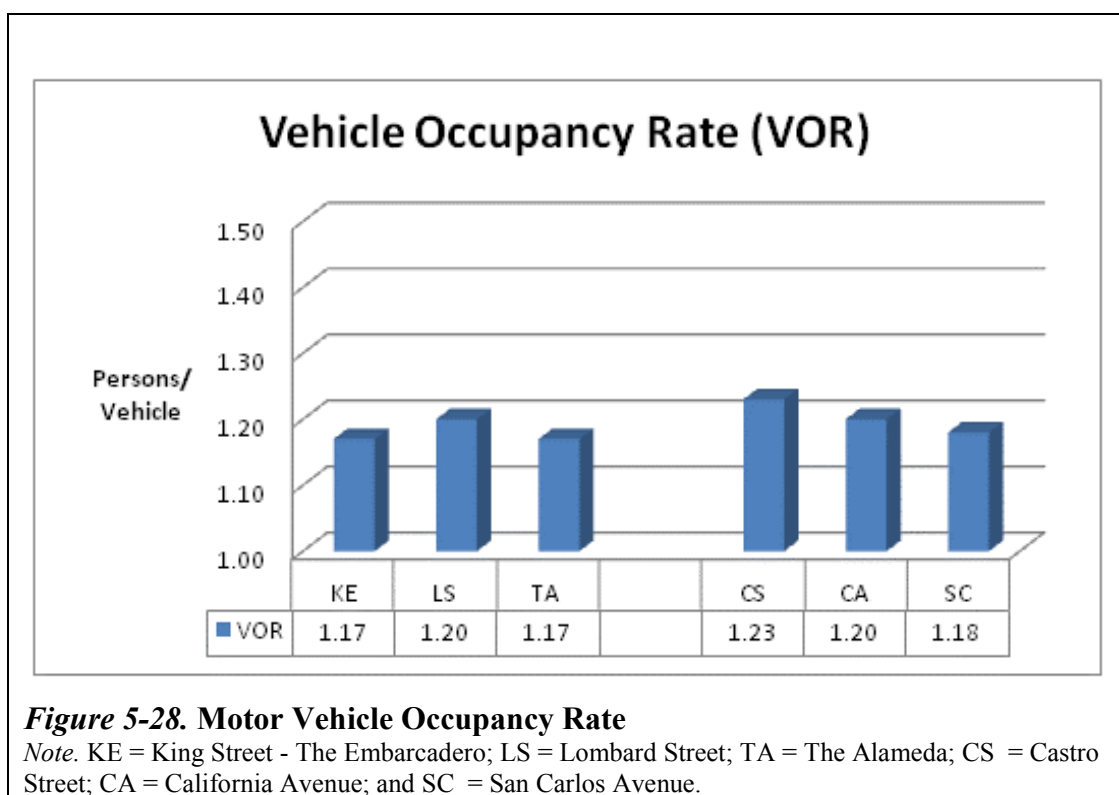


Figure 5-28. Motor Vehicle Occupancy Rate

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Motor vehicle travel lanes.

Not surprisingly, the two exemplary study streets either had the fewest or shared the status of having the fewest travel lanes in their cohort. King Street - The Embarcadero has the distinction of being an early version of a “complete street”, designed from the start to accommodate public transport, pedestrians, and cyclists alongside motor vehicle traffic. Castro Street was an early example of the revival and adaptation of the “context sensitive” main street. Figure 29 displays the number of motor vehicle travel lanes on each of the six streets.

⁷⁸ The average vehicle occupancy rate for work trips reported in the 2009 National Household Travel Survey was only 1.2, compared to 2.2 for social and recreational and 1.8 for social trips. Retrieved from the Transportation Energy Data Book web site (Chapter 8, Figure 8.2): http://cta.ornl.gov/data/tedb29/Edition29_Chapter08.pdf

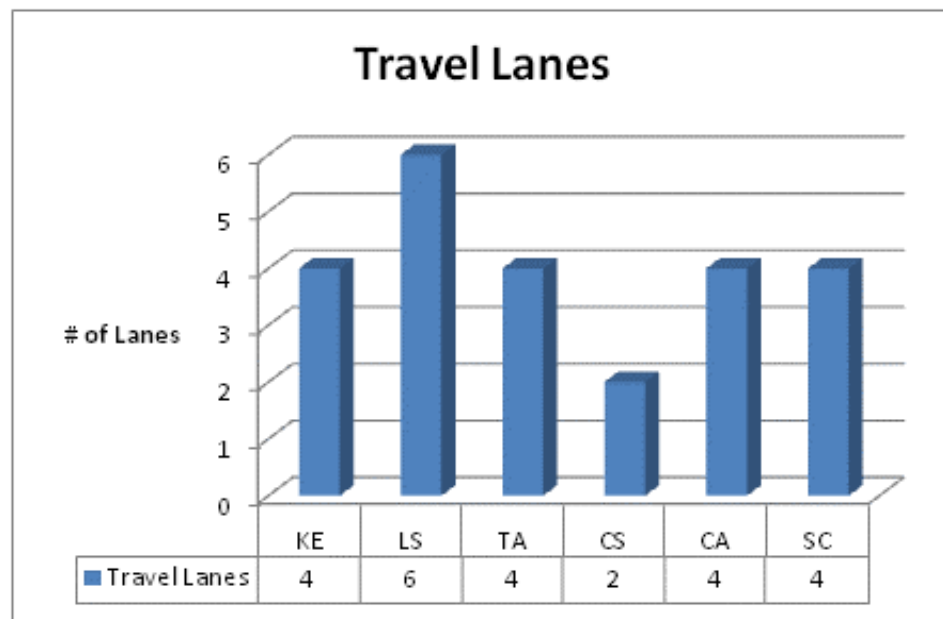


Figure 5-29. Motor Vehicle Travel Lanes

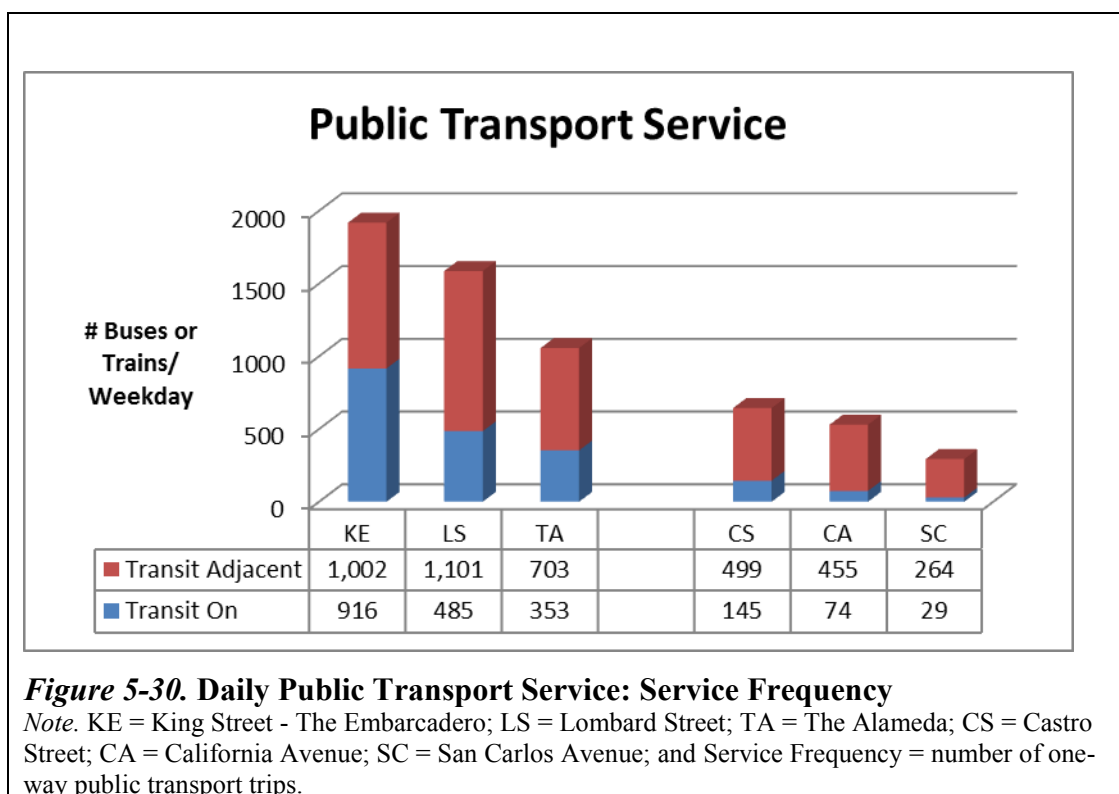
Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Public transport.

Public transport provision and use have a direct impact on the activity level and sustainability of streets. Transit by its nature generates a pedestrian presence on streets as people walk to and from, as well as wait at, public transport stops. Well-patronized public transport contributes to street sustainability by increasing the people flow along streets without adding to the car traffic volume.

Local transit service.

Local public transport service levels on or adjacent to the streets in the sample examined in this research study varied in a striking step-down fashion across each of the street cohorts and across the entire sample of street segments. The exemplary study street segments, King Street - The Embarcadero and Castro Street, each had the highest level of daily transit frequency or transit vehicle trips in their street cohort. Each of the three Big City arterial street segments, in turn, had higher levels of public transport service than did any of the street segments from the Small City cohort, as presented in Figure 30.



Regional passenger rail service.

The picture for regional rail passenger service is not so orderly. The Lombard Street segment is not in proximity to Caltrain or any other regional rail provider. The Alameda, on the other hand, like King Street- The Embarcadero, is within easy walking distance of a major terminus station on the Caltrain commuter rail line, which is also an important station for other regional passenger trains, including those operated by the Capitols and Altamont Commuter Express (ACE) commuter rail. Castro Street is an important intermediate transfer station on the Caltrain line for passenger interchange with Santa Clara Valley Transportation Authority (VTA) light rail trains and buses. Figure 31 illustrates the variations in amount of weekday regional passenger rail service proximate to the six street segments in this research study. Both California Avenue and San Carlos Avenue have passenger service that corresponds to the status that each has as a more typical intermediate station on a commuter rail line.

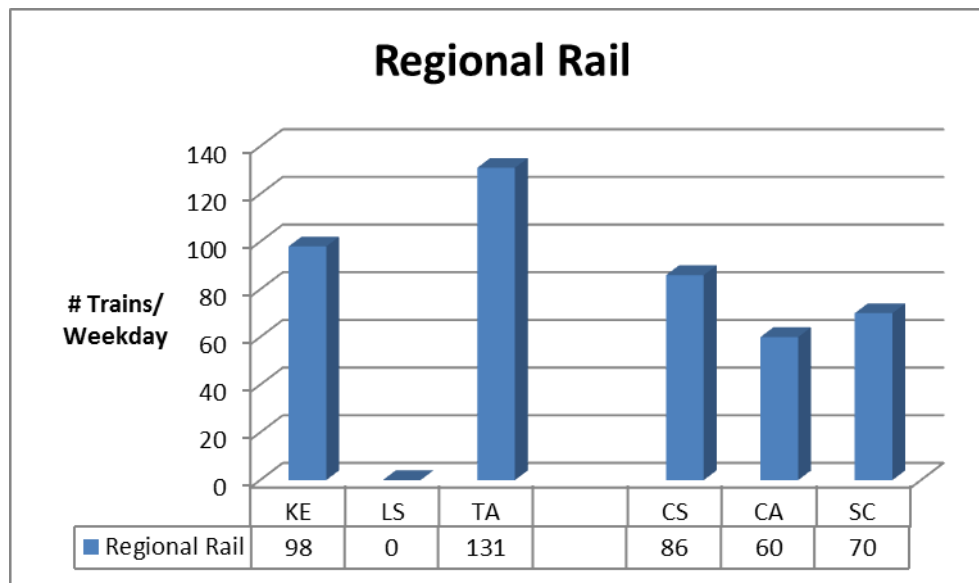


Figure 5-31. Regional Passenger Rail Service: Service Frequency

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Service Frequency = number of one-way public transport trips.

Public transport stops on the street.

Interestingly, the density of bus and light rail stops on the streets in this research study is in inverse proportion to the intensity of local public transport services available. In the case of King Street - The Embarcadero, this finding is misleading, as passenger capacity at light rail stops, as well as the capacity of the light rail trains for those waiting at the stops wishing to board, is much greater than for that of a typical urban bus stop. In the case of Castro Street, there are a limited number of passenger stop locations on its easterly reach, as the eastern end of this street segment has both a bus stop and a light rail station at the adjacent Mountain View transit center. This proximity reduces the need for bus stops on this portion of Castro Street itself. I counted public transit stops across the street from one another separately. In the case of SFMTA rail on King Street - The Embarcadero, a rail station serving both directions counted as one public transport stop. Figure 32 displays these data.

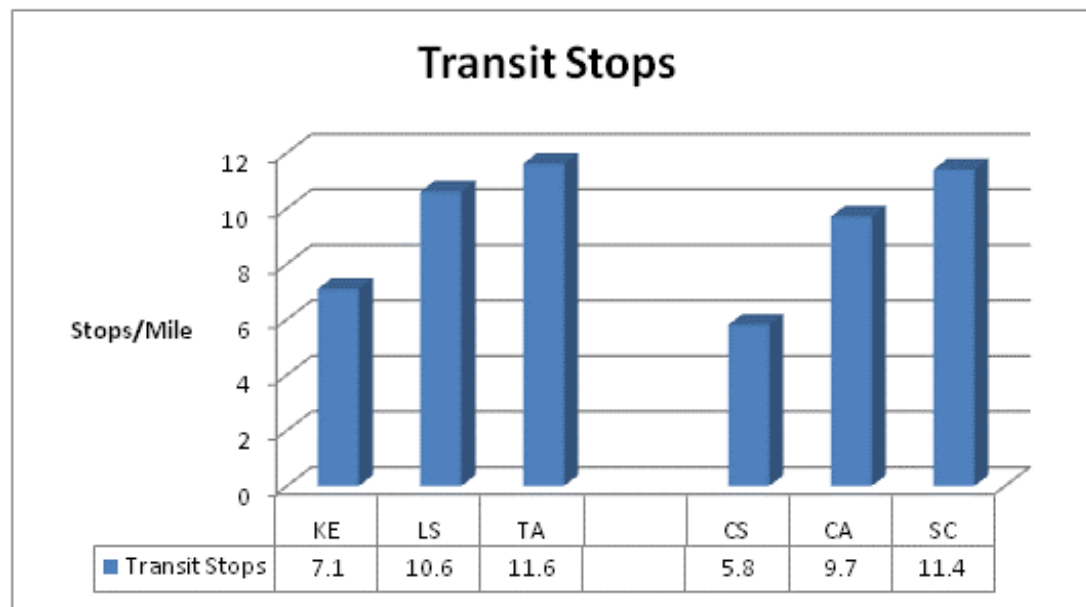


Figure 5-32. On-street Public Transport Stops

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Public transit use.

As Figure 33 reveals, King Street - The Embarcadero, the only street section with light rail service, had by far the highest number of public transport boardings of the six streets studied. As with public transport service data, boardings data are arrayed in step-down fashion. The exemplary streets in each cohort have both more public transport service and more transit boardings than their respective pair of control streets.

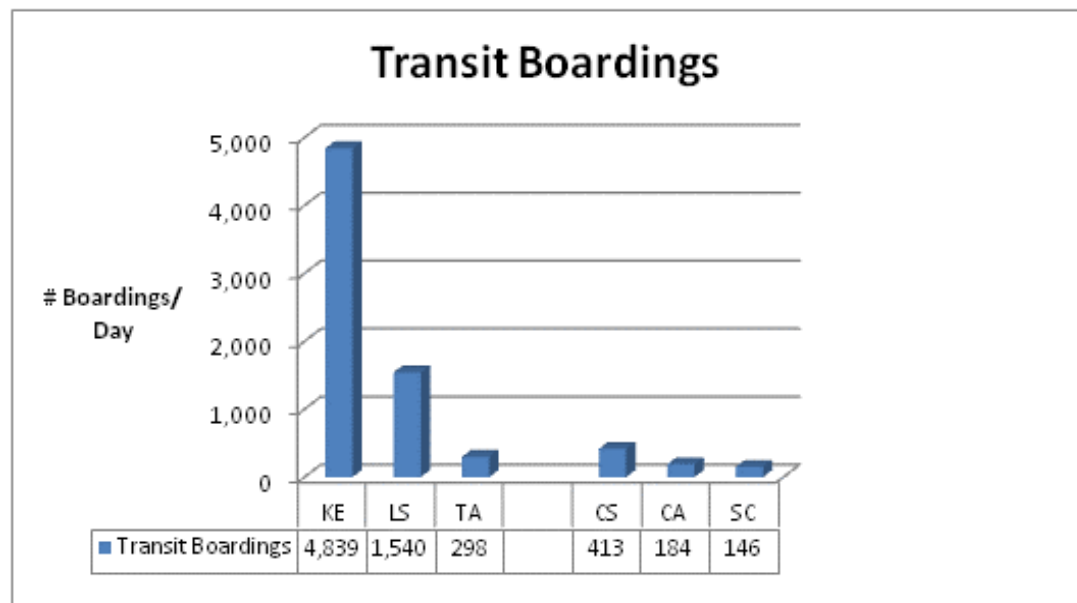


Figure 5-33. On-street Average Daily Public Transport Boardings

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Population and employment.

Active, sustainable streets are successful in serving both social and economic purposes. The number of people who live and/or work in the environs of a street is an important indicator of the potential that an individual street has to be both a community social venue and an economic engine.

King Street - The Embarcadero and Lombard Street are almost mirror opposites in terms of concentration of employment and population. The former street is close to many office and research facilities in the dramatically redeveloped Mission Bay and South Beach districts south of both the San Francisco Financial District and the tourist destinations of Fisherman's Wharf. The built-out, established neighborhoods of the Marina and Cow Hollow residential districts of San Francisco flank Lombard Street. Both The Alameda and Castro Street have approximately equal numbers of residents and jobs per square mile or kilometer within the quarter-mile catchment area on each side and at each end of these streets. The segment of California Avenue studied in this research effort is near the outer reaches of the Stanford Research Park, a large concentration of technology, legal, and financial employment. The environs of San Carlos Avenue, particularly its western reach, comprise comparatively low-density residential land uses.

In general, as might be expected, the cohort of Big City arterial street segments had a greater total density of population and employment nearby than did the Small City cohort. The Alameda, an exception to this general rule, was a street still in the early stages of re-development to more intensive use in 2007, the year in which I collected these data (as well as companion data on street use). Figure 34 summarizes employment and population density per square mile for each of the six street segments.

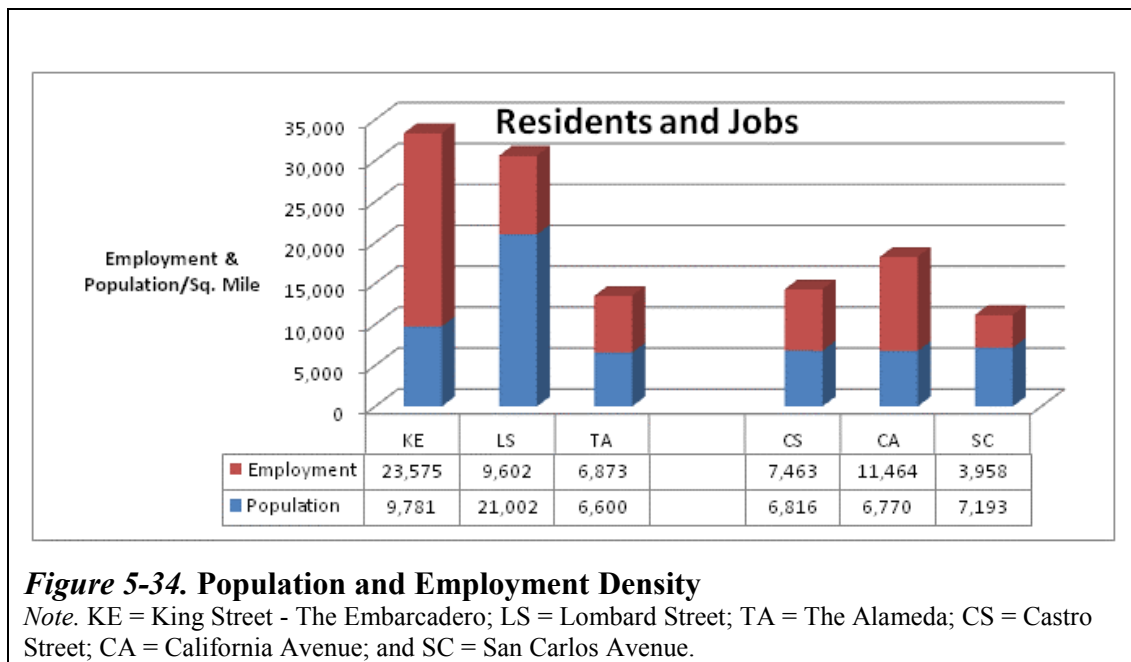


Figure 5-34. Population and Employment Density

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

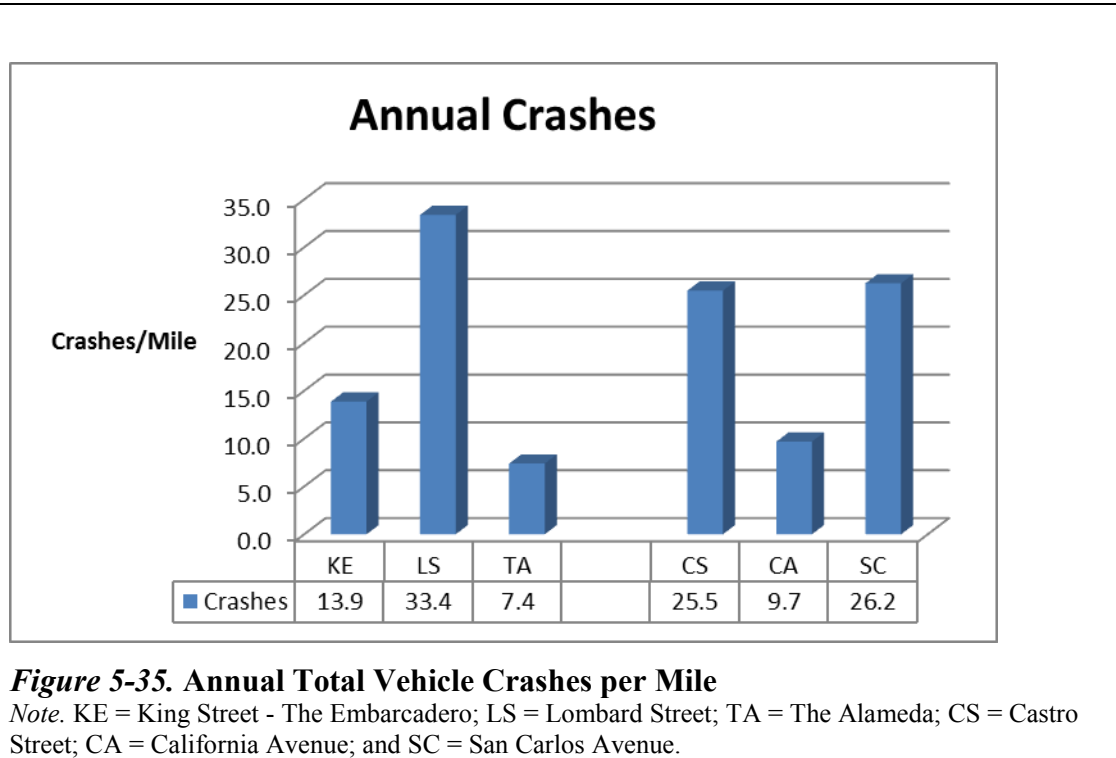
Travel safety.

Travel safety is an indicator of the sustainability of a street. At the same time, how safe a street is for travel may both reflect and influence the amount of street activity.

Vehicle crashes.

A comparison of total crashes a year, derived from a data set consisting of five and two-thirds years of data, presents a study in contrast for King Street - The Embarcadero and Castro Street. While total annual crashes along the former were far below the number that occurred on Lombard Street, the most crash prone of the three Big City arterial street segments, Castro Street had nearly the same number of crashes as San Carlos Avenue, the Small City arterial street segment with the most crashes. California Avenue, a dead-end street with comparatively low traffic volumes

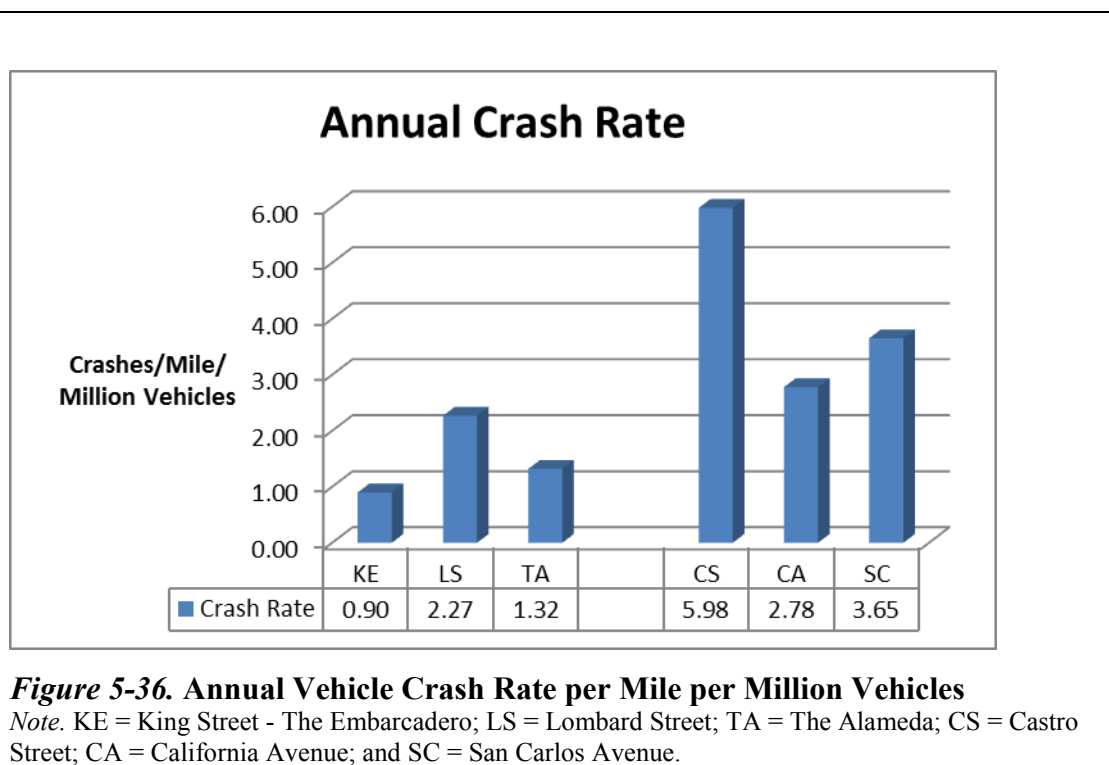
and speeds, and The Alameda, the least busy street segment in Big City arterial group, both experienced a comparatively low number of crashes. Figure 35 contains the array of annual crash statistics for the six street segments.



Adjusting aggregate crash totals by the traffic volumes on each street presents a somewhat different picture. As summarized in Figure 36, busy King Street -The Embarcadero had the lowest crash rate in the Big City street segment group and among the six streets in this research investigation. Castro Street, on the other hand, had the highest crash rate of all the street segments and California Avenue rose to third rank overall, although with the lowest crash rate among the Small City streets. The Small City group as a whole had a higher crash rate than did their companion Big City cohort.

One explanation for this difference may be that all three of the former streets had head-in angle parking along part of their reach, while none of the latter group had any angle parking. The un-parking maneuver in angle parking requires greater intrusion into the adjoining travel lane or lanes, as well as reduced visibility of through vehicles available to the drivers of un-parking vehicles, compared to that required for parallel parking (Oregon Department of Transportation, 2001). This combination of greater exposure to potential conflict and less visibility increases

crash risk and is at least a contributing factor in the observed data. A mitigating factor, however, is that the angle parking and unparking maneuver reduced travel speeds on a street as approaching drivers slow down. This traffic calming effect thus reduces crash severity.



Crash severity.

A comparison of casualty rates across the sample of six streets tells another tale. Both Castro Street and King Street - The Embarcadero had far fewer traffic crash casualties than the most casualty-prone street segment in their respective cohorts. Lombard Street, despite having about the same daily traffic as King Street - The Embarcadero, experienced nearly four times the casualties as the latter street segment. Dead-end, low-speed, and lightly travelled California Avenue had dramatically fewer casualties than had any other street segment in this research study. Not surprisingly, The Alameda, with the lowest traffic volume among the three Big City streets, also experienced the fewest number of crash casualties, although not much less than that for King Street – The Embarcadero. Figure 37 shows the comparative number of casualties by street segment.

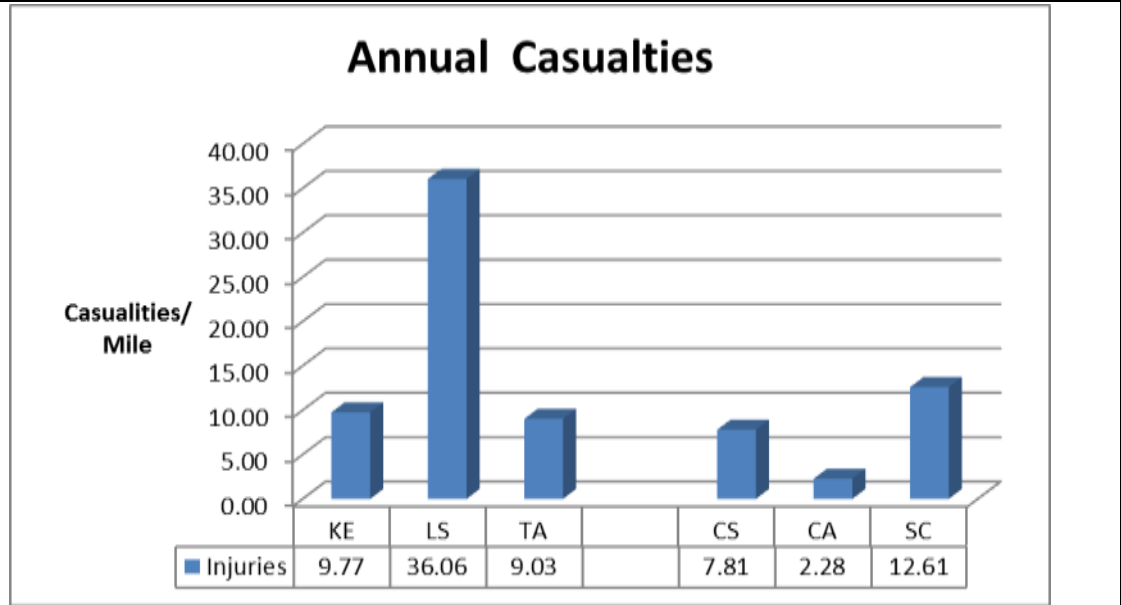


Figure 5-37. Annual Casualties per Mile

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Adjusting total number of casualties by traffic volume on each street to determine comparative crash casualty rates alters the rankings. King Street - The Embarcadero had the lowest casualty rate of all the streets and by far the smallest of the Big City cohort. California Avenue remained the least casualty-prone Small City arterial and Lombard Street the most casualty-prone across the sample of six street segments. As can be seen in Figure 38, no clear pattern emerges in comparing the casualty rates of the Big City and Small City cohorts.

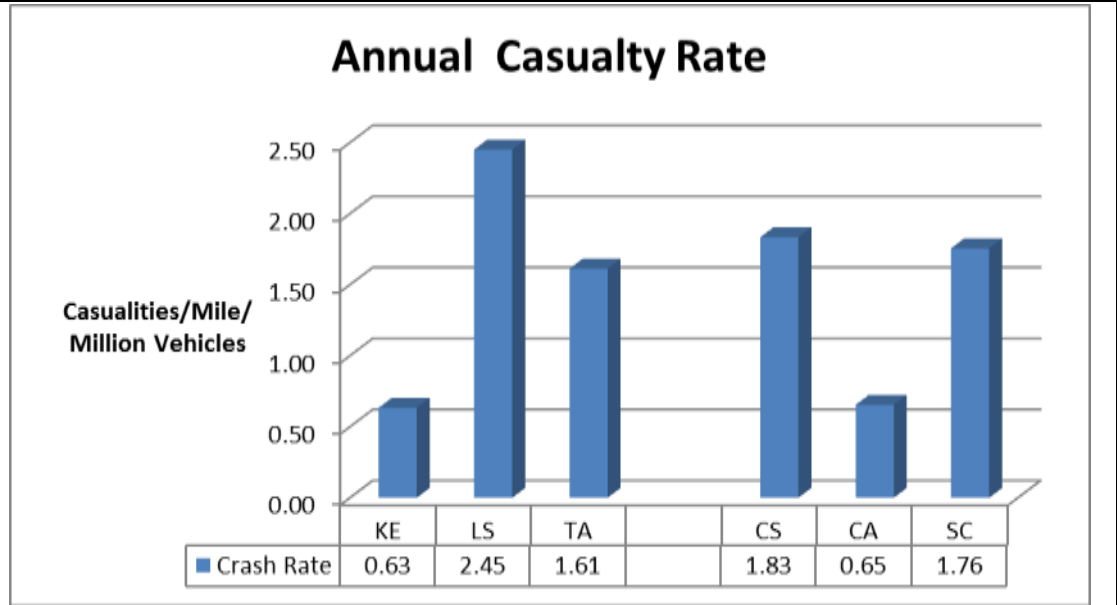


Figure 5-38. Annual Casualties per Mile per Million Vehicles

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

There is a pattern in the comparison of the two cohorts regarding the number of casualties per crash, which is an indicator of crash severity. The Big City arterials as a group had markedly more casualties for each crash than did the Small City arterials. Notably, King Street - The Embarcadero had the lowest rate of crash severity among the former group and Castro Street had a rate just above California Avenue, the street with the lowest vehicle speeds, within the latter cohort. The Alameda, in contrast, had the highest rate of crash severity among all six streets. Figure 39 displays these findings.

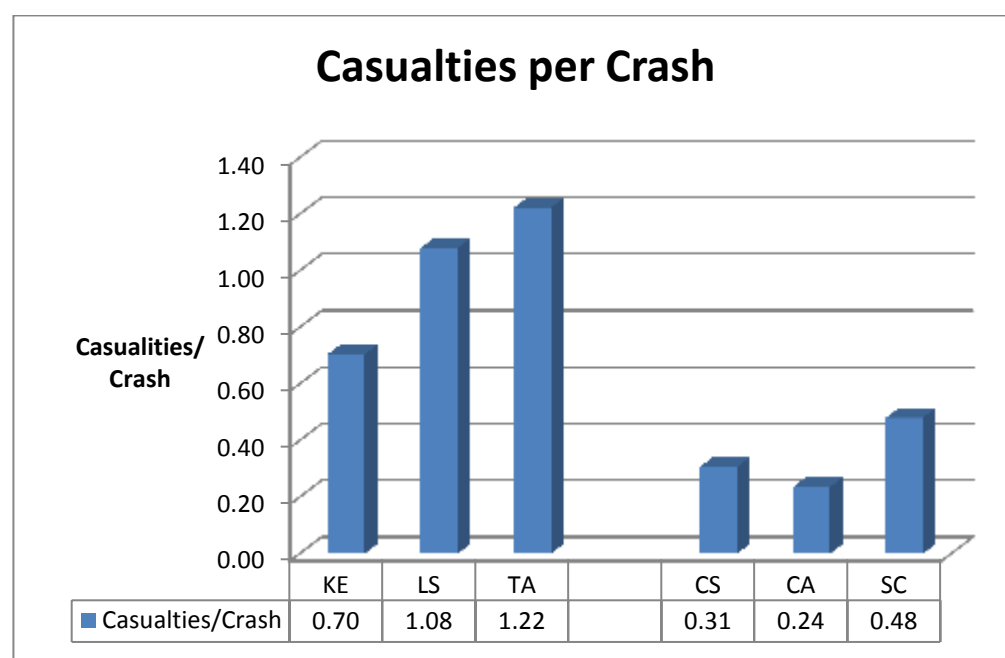


Figure 5-39. Casualties per Crash

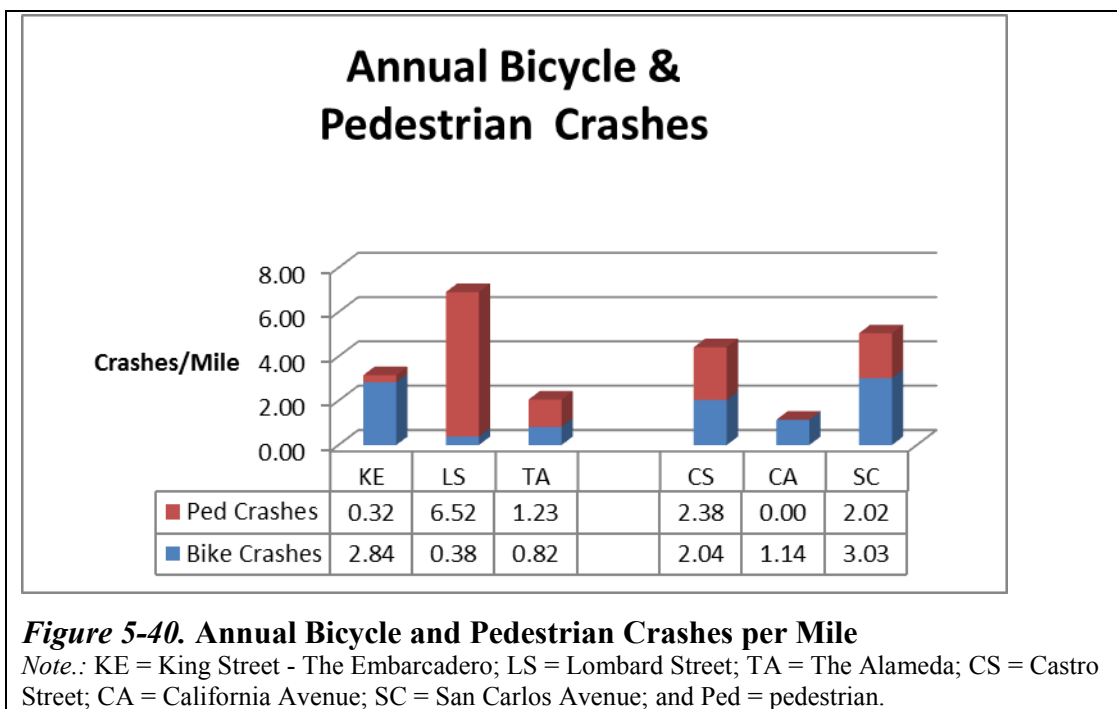
Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Pedestrian and bicycle crashes.

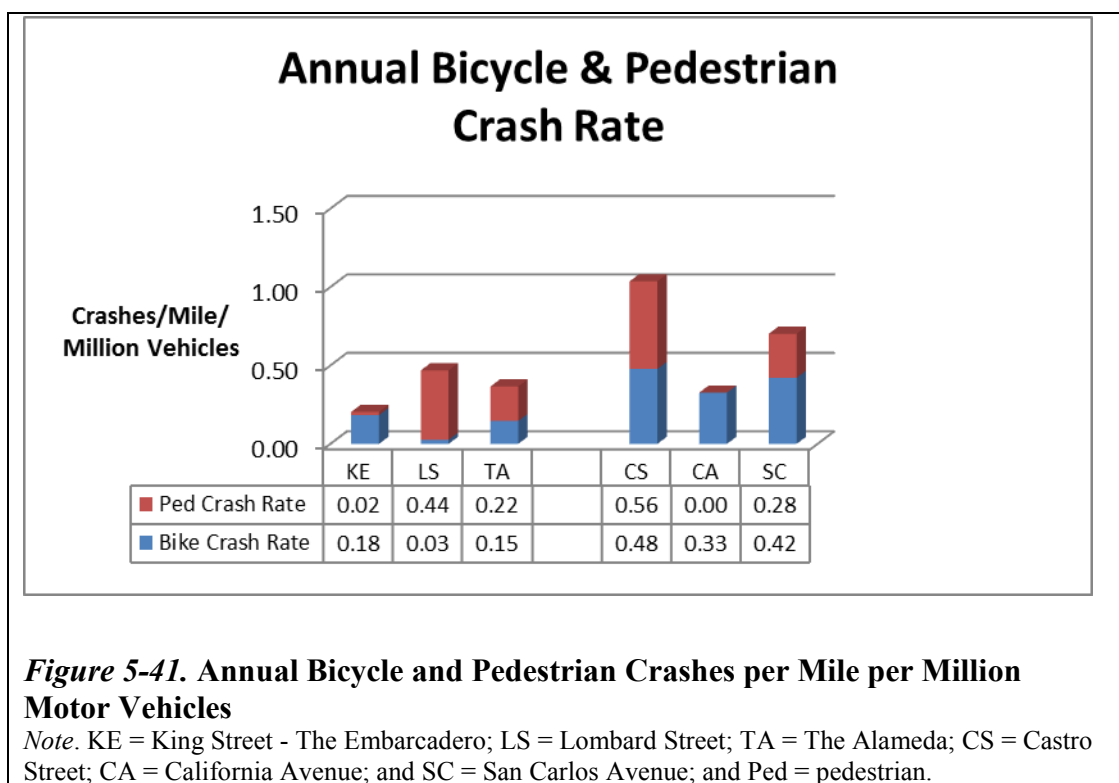
Lombard Street had unquestionably the highest number of pedestrian crashes of all six streets, to such an extent that even with very few bicycle crashes, Lombard also had the greatest number of total bicycle and pedestrian crashes. It is important to note that the comparatively low total of bicycle crashes on Lombard may not represent its relative safety for cycling, but rather reflect the very low number of cyclists who dare to use the street. Few crashes may create the illusion that the street is safer for cyclists. Instead, a low crash rate may be assignable to avoidance behavior, similar to the effect on the pedestrian crash rate when parents refuse to allow their children to cross what they perceive to be a dangerous street (Hillman, 1992).

King Street - The Embarcadero and Lombard Street are on opposite poles in aggregate number of pedestrian crashes, with the latter street having an astonishing twenty times as many such crashes as the former. San Carlos Avenue had the highest number of bicycle crashes, possibly due in part to a combination of comparatively high motor vehicle speeds and the discontinuity created by having cycle lanes on only about half of the street segment. There is increased cyclist exposure to potential conflict with motor vehicle traffic increases in the transition from bicycle lanes to

mixed flow travel lanes (Krizek & Rio, 2005). Comparatively low-speed, low-motor vehicle volume California Avenue had the fewest pedestrian crashes and a relatively low number of bicycle crashes, despite ranking second in bicycle volumes among the six street segments. Figure 40 reports on the comparative number of bicycle and pedestrian crashes across the sample of streets.



Adjusting total bicycle and pedestrian crashes by motor vehicle volumes changes the comparative rankings across the street segments. Despite its comparatively narrow cross-section and design features such as bulb-outs and raised center medians at various pedestrian crossings along its reach, Castro Street had the highest pedestrian crash rate. However, these data are by their nature biased against the relatively lower motor vehicle volume streets such as Castro Street. They also do not take into account comparative pedestrian volumes, which, along with motor vehicle volumes and motor vehicle speeds, contribute to the extent of pedestrian exposure to crash risk. Figure 41 exhibits pedestrian and bicycle crash rates, adjusted for motor vehicle volumes.



Figures 42 and 43 display annual pedestrian and bicycle crashes per mile per year, adjusted by observed/imputed⁷⁹ number of pedestrians or bicyclists per year. These adjustments changed the comparative ranking of streets in bicycle and pedestrian crash rates. Castro Street fell from having the first to the third highest pedestrian crash rate and from first to second highest in bicycle crash rate. Nevertheless, San Carlos Avenue had a nearly four times higher pedestrian crash rate for pedestrians and almost five times higher for bicyclists compared to that for Castro Street. King Street - The Embarcadero remained the second lowest in pedestrian crash rate and fell from third to second lowest in bicycle crash rate.

The low motor vehicle speed and volume, as well as the relatively high cycling volume on the street undoubtedly make California Avenue the safest of the six streets sections for bicyclists, especially when taking the number of bicyclists on the street into account. In contrast, the lower cycling volume on Castro Street and lack of space for cycling (either in continuous, dedicated bicycle lanes or wide curb

⁷⁹ This imputation is approximate only in that it assumes that pedestrian or bicycle counts per hour for the observation periods (late morning and early afternoon and late afternoon/early evening on weekdays) are representative of these counts during an average observational hour of the day. These hourly averages were extrapolated across a 16-hour day (assuming that there is typically little walking and bicycling on the six street segment overnight) and a 365-day year to arrive at imputed annual averages.

lanes) were likely contributing factors to that street's comparatively high bicycle crash rate.

King Street - The Embarcadero remained the second lowest of the six streets in pedestrian crash rate and fell from third to second lowest in bicycle crash rate. Pedestrian safety conditions, represented by pedestrian crash rates as well as adjusted crash rates, are dramatically better on King Street - The Embarcadero than on any of the other arterial street segments apart from California Avenue. Pedestrian safety factors that may bear upon this performance include wide, continuous raised center medians that protect pedestrians crossing King Street - The Embarcadero and traffic signal controls at all pedestrian crossings.

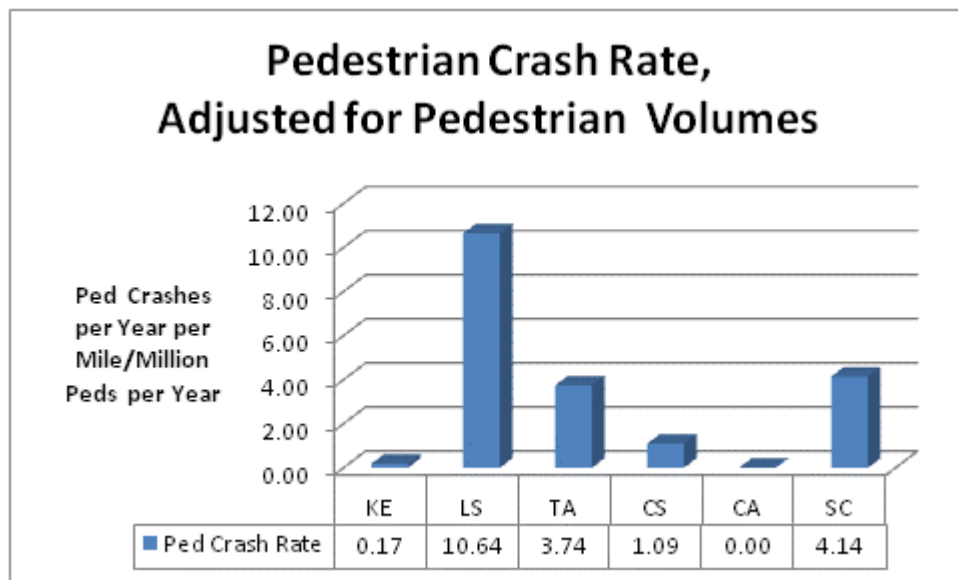


Figure 5-42. Annual Pedestrian Crashes per Mile per Million Pedestrians

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; Peds = pedestrians; and Ped = pedestrian. Pedestrian volumes approximated by assuming hourly late morning/early afternoon and late afternoon/early evening pedestrian counts represent hourly averages for a 16-hour day (excluding 8 night time hours), extrapolated to the entire year.

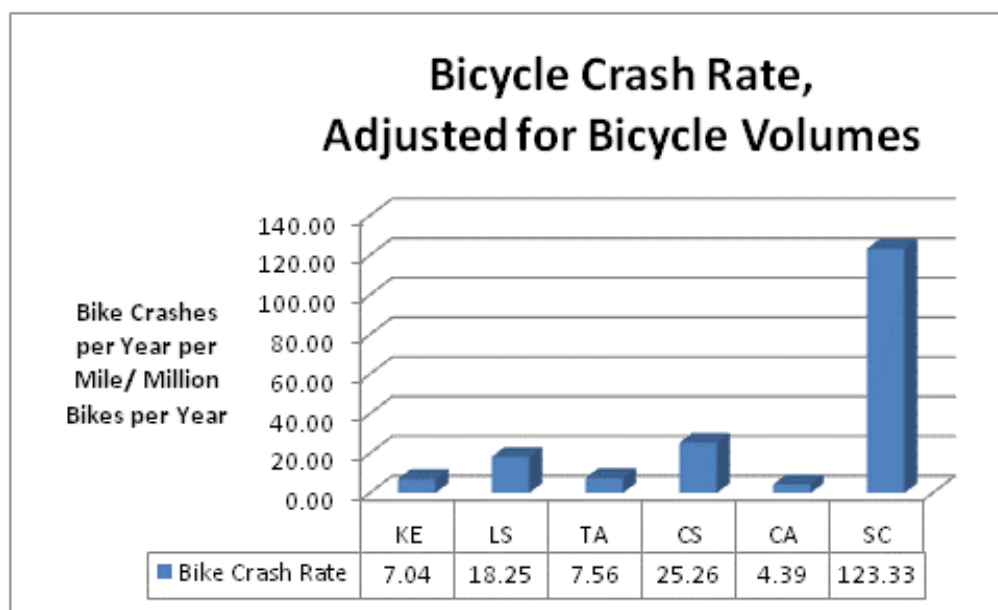


Figure 5-43. Annual Bicycle Crashes per Mile per Million Bicycles

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue. Bicycle volumes approximated by assuming hourly late morning/early afternoon and late afternoon/early evening bicycle counts represent hourly averages for a 16-hour day (excluding 8 night time hours), extrapolated to the entire year.

Comparison of the proportion of total pedestrian volumes to proportion of total pedestrian crashes helps to illuminate the degree of hazard facing pedestrians crossing streets. Figure 44 shows these comparative shares. Figure 45 displays the Comparative Pedestrian Safety Index, calculated by subtracting the share of total pedestrian crashes from the share of total pedestrian volumes for each street section. King – The Embarcadero, the street segment with the highest daily motor vehicle traffic volume, also had the highest Pedestrian Safety Index value. Only California Avenue, the street section with the lowest average daily traffic volume and the lowest measured 85th percentile motor vehicle speed, had a comparable Pedestrian Safety Index number. Castro Street had the third highest and only other positive Index value. The value for Lombard Street was notably low.

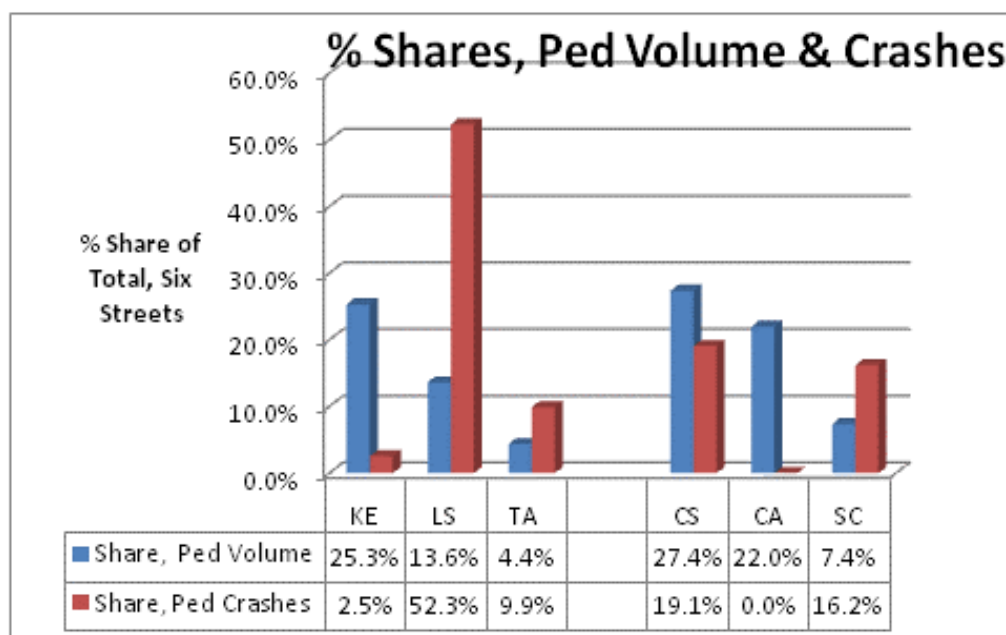


Figure 5-44. Proportionate Shares of Pedestrian Volumes and Crashes Across Six Streets

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and PED = pedestrian.

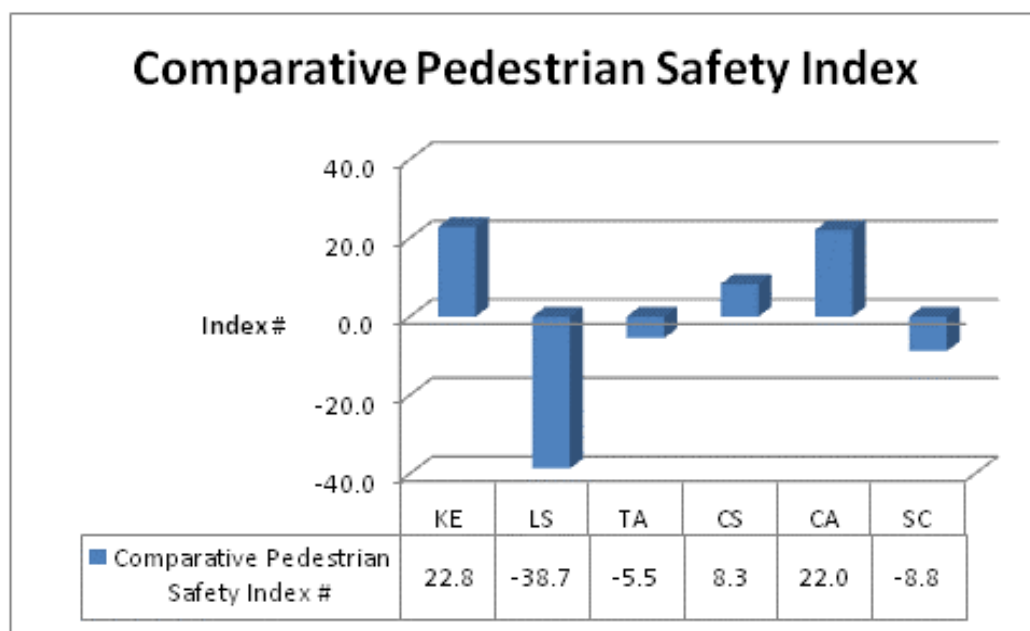
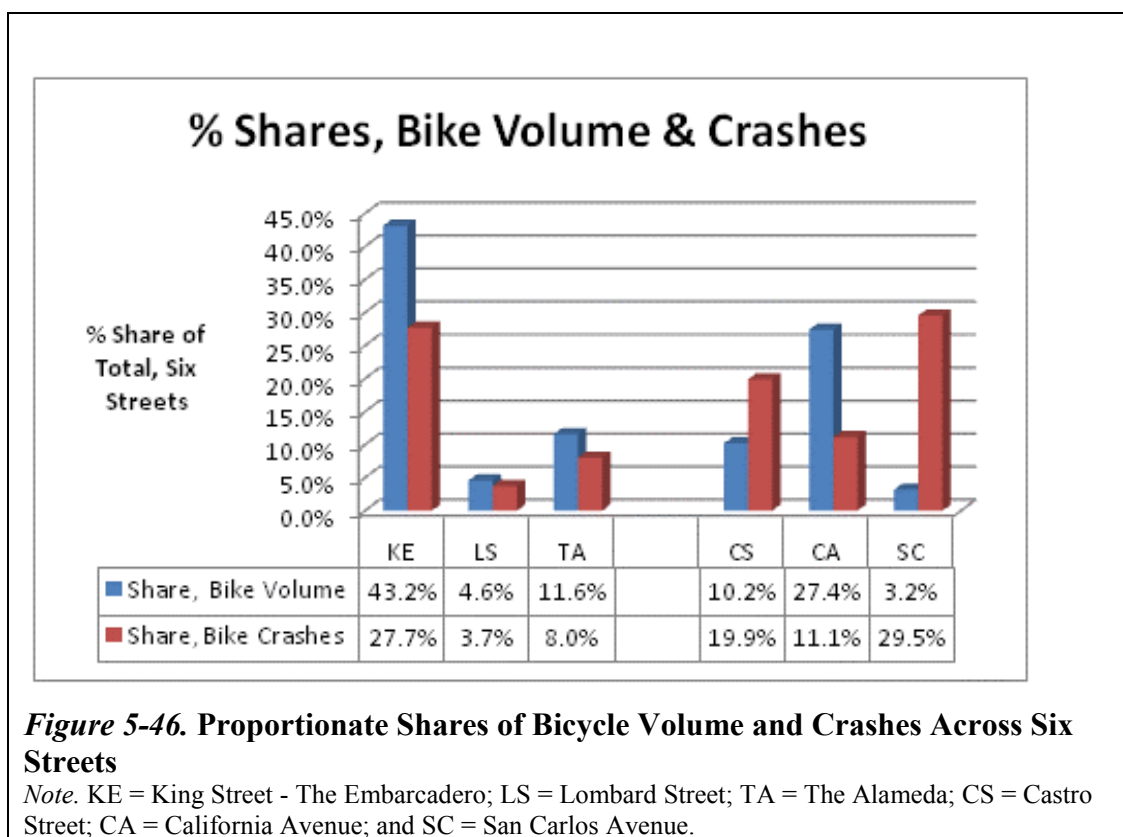


Figure 5-45. Shares of Annual Pedestrian Crashes Subtracted from Shares of Annual Pedestrian Volumes: The Comparative Pedestrian Safety Index

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Analogous to the case of pedestrians, comparison of the proportion of total bicycle volumes to proportion of total bicycle crashes illuminates the amount of safety risk facing cyclists. Figure 46 reveals these comparative shares. Figure 47 presents the Comparative Bicycle Safety Index, calculated by subtracting the share of total bicycle crashes from the share of total bicycle volumes for each street.

San Carlos Avenue, a street section with cycle lanes over approximately half its reach, had a Comparative Bicycle Safety Index that was nearly the opposite of that for California Avenue, the street with the highest Index value, and also much lower than that of any of the other streets. The Comparative Bicycle Safety Index value for King Street - The Embarcadero was close to that of California Avenue. Castro Street was the second least safe street for cycling by this measure.



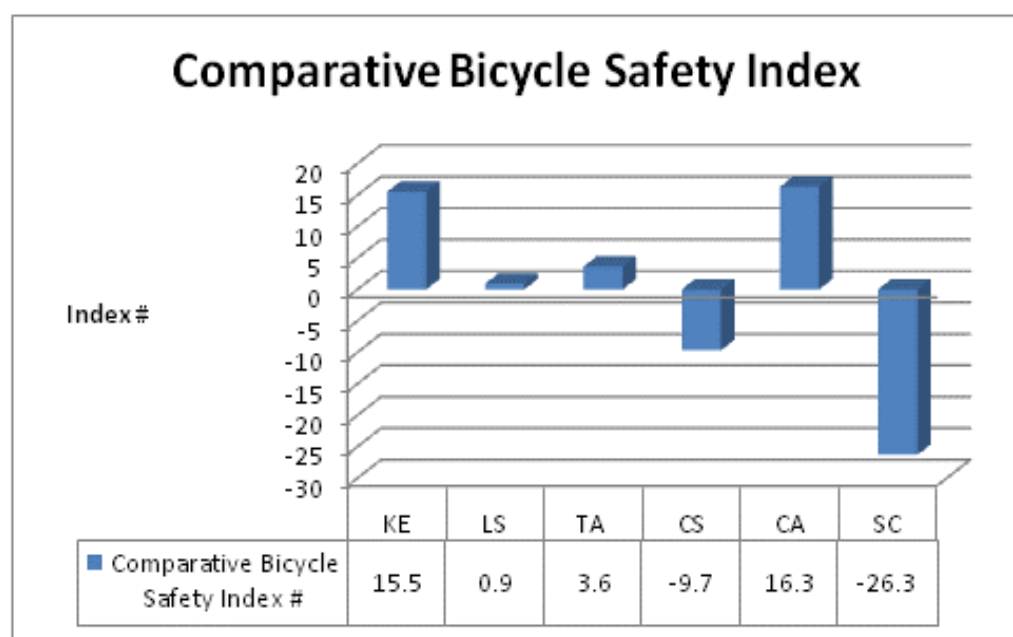


Figure 5-47. Shares of Annual Bicycle Crashes Subtracted from Shares of Annual Bicycle Volumes: The Comparative Bicycle Safety Index

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Stakeholder assessment.

If streets are to serve the needs of people, the best judges of how well they do so are people who use the streets. People have a variety of purposes in their street use. Arguably, the stake people have in a street is proportionate to the amount of time spent on and near the street. Traffic conditions greatly affect the quality of life of residents who live along a street (Appleyard, et al., 1981). Business owners depend for their livelihood on the accessibility of their businesses to their customers, the safety of the streets on which their businesses are located, and even the degree of amenity provided to their customers by the streetscape. All those who spend time sitting at a curbside café table, window-shopping, chatting with friends, and engaging in other such discretionary activities are important stakeholders too (Gehl, 1996).

I asked stakeholders on each of the six street sections in this research study for their views on street qualities and performance. Stakeholder groups included residents, business people, customers, commuters, and visitors. I consulted these groups by means of questionnaires, focus groups, and a visual assessment exercise. Chapter 4 summarized survey responses to questions on modal use, purpose of visits

to the street, and neighborhood of residence for each street. The sub-sections to follow present these stakeholder assessments.

Street user's survey.

This section presents a summary of responses by street users to questions about street comfort, safety, attractiveness, convenience, activity, and importance. . Results of statistical significance testing accompany these findings⁸⁰. This summary includes tabulations of the most frequent respondent comments about what aspects of each street they liked and disliked, illustrated by quotations from respondents.⁸¹

Street attributes as experienced by street users.

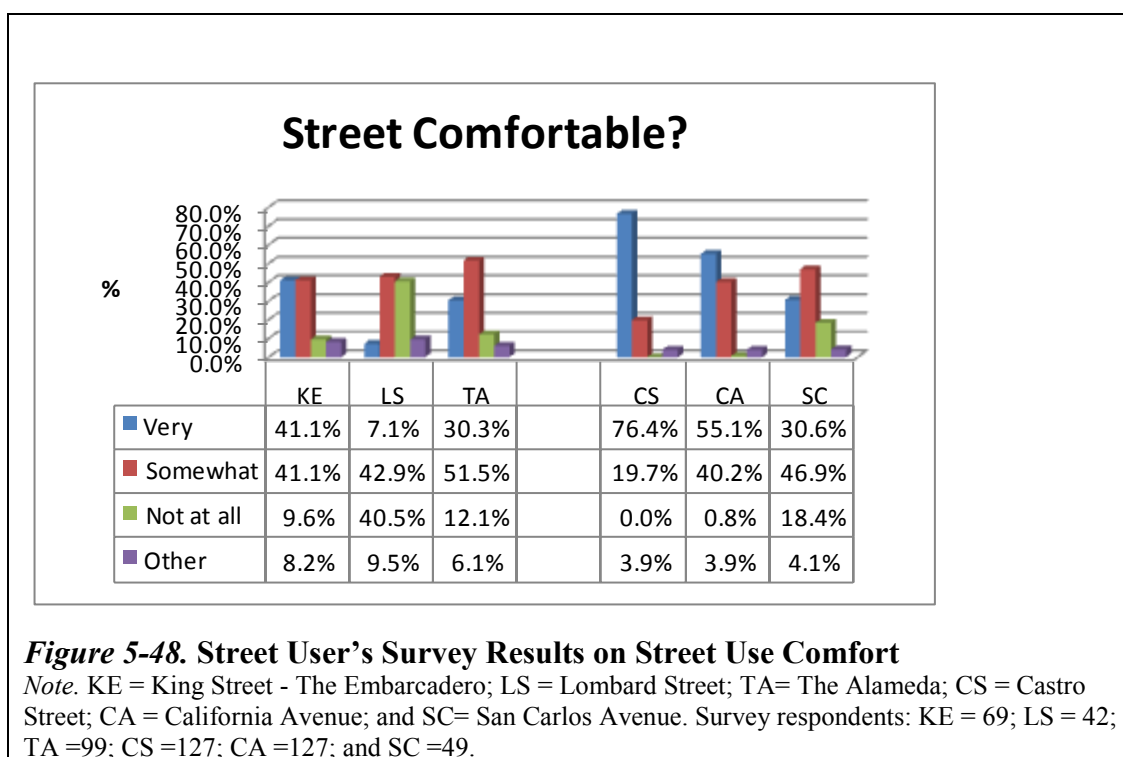
Figure 48 summarizes responses to the question about how comfortable each street section was to use. Responses showed that the two study streets, King Street - The Embarcadero and Castro Street, were most comfortable in their respective cohorts. Respondents in general assessed the group of Small City street sections as more comfortable to use than the Big City street sections. Lombard Street received the lowest assessment of all on the comfort attribute. One survey respondent may have summed up this appraisal of Lombard with the following observation, written in the open-ended comments section: "It's uncomfortable to do much except drive straight to the bridge. That's what I think most people use it for. That's probably pretty comfortable for them."

Tables 2 and 3 show the results of a difference in proportions test of the first and second highest proportion of very comfortable responses on each of the two street segment cohorts (i.e. King Street – The Embarcadero and The Alameda for the Big City and Castro Street and California Avenue for the Small City cohorts, respectively). In the first case, the hypothesis that King Street - The Embarcadero had the same or a lesser proportion of very comfortable responses as The Alameda or California Avenue, respectively, was not rejected at an $\alpha = .05$ (or 95% confidence level), but was rejected at the $\alpha = .10$ level of significance (or 90% confidence level). Thus, there was a statistically significant difference between the two proportions, but at a less robust level of significance than $\alpha = .05$. Nevertheless, this result was

⁸⁰ A one-tailed test for difference of proportions (Brase & Brace, 2006) with a critical value of $\alpha = .05$ was used to determine if the proportions tested were significantly different from one another. The null hypothesis was that there was no difference between two proportions. This hypothesis was rejected at the significance level of $\alpha = .05$ if the test statistic was greater than the test critical value. It should be noted that there still might be a difference between the proportions, but not one that is statistically significant at $\alpha = .05$.

⁸¹ A transcript of all respondents' written comments is available at the URDMS Curtin University research data repository.

impressive since daily vehicle traffic volume on King Street – The Embarcadero is two and three-quarters times higher than that for The Alameda. In sum, one may plausibly assert that King Street - The Embarcadero was a very comfortable street to a significantly larger proportion of street users than was The Alameda, at least at $\alpha = .10$ level of significance. In contrast, Castro Street was a very comfortable street to a significantly larger proportion of street users than was California Avenue at the more stringent $\alpha = .05$ level of significance (or 95% confidence level).⁸²



⁸²

Detailed, cross-tabulated responses to this question, by most frequent mode of access to each of the six streets, are available in the URDMS Curtin University research data repository.

Table 5-2

Difference in Proportions Test for Very Comfortable: King Street – The Embarcadero and The Alameda

Variable/parameters	Street/respondents	
Comfort	KE	TA
p =	30	30
n =	73	99
$\alpha = .05, .10, 1\text{-tailed test}$		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$\alpha = .05$		
$z_{\text{test}} = 1.307$		
$z_{\text{critical}} = 1.645$		
$z_{\text{test}} < z_{\text{critical}}$, therefore H_o is not rejected at $\alpha = .05$		
$\alpha = .10$		
$z_{\text{test}} = 1.307$		
$z_{\text{critical}} = 1.282$		
$z_{\text{test}} > z_{\text{critical}}$, therefore H_o is rejected at $\alpha = .10$		

Note. KE = King Street – The Embarcadero and TA = The Alameda.

Table 5-3

Difference in Proportions Test for Very Comfortable: Castro Street and California Avenue

Variable/parameters	Street	
	CS	CA
Comfort		
p =	97	70
n =	127	127
$\alpha = .05, 1\text{-tailed test}$		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{\text{test}} = 3.438$		
$z_{\text{critical}} = 1.645$		
$z_{\text{test}} > z_{\text{critical}}$, therefore H_o is rejected.		

Note. CS = Castro Street and CA = California Avenue.

Figure 49 displays responses to the question about how safe each street section was to use. Respondents judged the two study streets, King Street - The Embarcadero and Castro Street, to be the safest in their respective street cohorts,

although Castro Street's advantage over the California Avenue, the Small City street with the second highest very safe response proportion, was slight. As with the assessment of how comfortable a street is to use, those who responded to the survey viewed the group of Small City street segments as generally safer to use than the Big City cohort street sections. Lombard Street received the lowest assessment of all on safety. Respondents appraised San Carlos Avenue as the least safe of the three Small City arterial street segments. Respondent unease about the safety of using Lombard Street shows in the following respondent comment: "It's a wreck about to happen - at least that's how it feels. It's for cars and little else is able to take hold there maybe because of that."

Tables 4 and 5 contain findings from a difference in proportion test of the two highest proportions of very safe responses on each of the two street segment cohorts (i.e. King Street – The Embarcadero and The Alameda for the Big City and Castro Street and California Avenue for the Small City cohorts). In the Big City street group, the hypothesis that King Street - The Embarcadero had the same or a lesser proportion of very safe responses than The Alameda was rejected at the $\alpha = .05$ level of significance. This indicates a statistically significant difference in the proportion of this response with respect to the two streets. However, the same hypothesis for Castro Street with respect to California Avenue, was not rejected at either the $\alpha = .05$ or $\alpha = .10$ level of significance. Hence, from a statistical perspective, there was no difference in the perceptions of very safe conditions by survey respondents of each of these latter two streets. Even so, this too is remarkable since California Avenue is a dead-end street, thus has a lower volume of traffic and lower motor vehicle speeds than does Castro Street.

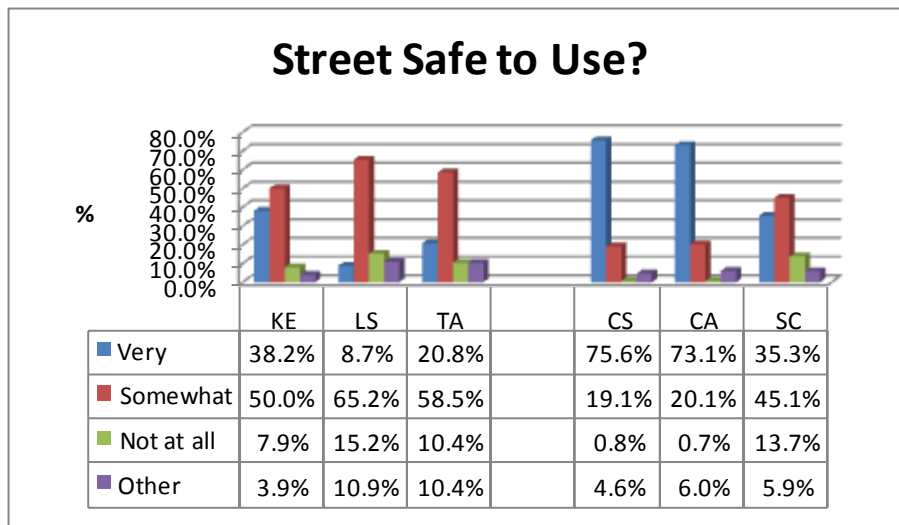


Figure 5-49. Street User's Survey Results on Street Use Safety

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue. Survey Respondents: KE = 76; LS = 46; TA = 106; CS = 131; CA = 134; and SC = 51.

Table 5-4

Difference in Proportions Test for Very Safe: King Street – The Embarcadero and The Alameda

Variable/parameters	Street	
	KE	TA
Safety		
p =	29	22
n =	76	106
$\alpha = .05$, 1 –tailed test		
$H_0 = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$p_a - p_b = 0.2126$		
$z_{test} = 2.412$		
$z_{critical} = 1.645$		
$z_{test} > z_{critical}$, therefore H_0 is rejected.		

Note. KE = King Street – The Embarcadero and TA = The Alameda.

Table 5-5

Difference in Proportions Test for Very Safe: Castro Street and California Avenue

Variable/parameters	Street	
	CS	CA
Safety		
p =	99	98
n =	131	134
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = .314$		
$z_{critical} = 1.645$		
$z_{test} > z_{critical}$, therefore H_o is not rejected.		

Note. CS = Castro Street and CA = California Avenue.

These comparative safety results based on subjective assessment of street users present an interesting contrast with the objective data on crash history presented in an earlier section of this chapter. Both objective data and subjective assessment of traffic safety align well for King Street - The Embarcadero, a street with the safest crash history of the Big City arterial streets. A different situation existed with respect to Castro Street. While respondents deemed Castro Street to be just as safe as dead-end, low-speed California Avenue, crash statistics across the board show Castro Street to be a less safe traffic environment than California Avenue. It is possible to explain some of this difference by the psychologically protective effect of safety in numbers as perceived by street users, both in terms of traffic safety and feeling of personal security, on busier Castro Street. Pedestrians on Castro Street enjoy shorter crossing distances, hence less exposure to moving motor vehicle traffic, due to bulb-outs at crossings and one less travel lane in each direction. Whereas in all likelihood street users perceive California Avenue as very safe for quite different reasons, including being dead-end, low speed, and low volume.

Figure 50 shows responses to the question about the attractiveness of each street section. Respondents rated the two study streets, King Street - The Embarcadero and Castro Street, the most attractive in their respective cohorts. In general, those using the group of Small City street sections saw them to be more attractive than the Big City street cohort sections. Lombard Street received the lowest appraisal of all on attractiveness. Respondents gave California Avenue the smallest

proportion of very attractive ratings of the three Small City arterial street segments. The following comment exemplifies respondent views on the attractiveness of Lombard Street: “The best parts are the pieces that haven't been touched in 30 odd years. The rest of it is newer but more hideous.” On the other hand, one Castro Street respondent gave the following testimonial: “Castro Street is the most beautiful downtown street I have seen around here”.

Table 6 and Table 7 reflect the results of a difference in proportion test of the first and second highest proportion of very attractive responses on each of the two street segment cohorts. In the Big City street group, the hypothesis that King Street - The Embarcadero had the same or a lesser proportion of very attractive responses than The Alameda was rejected at an $\alpha=.05$ level of significance. The same hypothesis for Castro Street with respect to San Carlos Avenue was also rejected at $\alpha=.05$. Although beauty is “in the eye of the beholder”, King Street - The Embarcadero and Castro Street were clear winners in the street beauty contest poll.

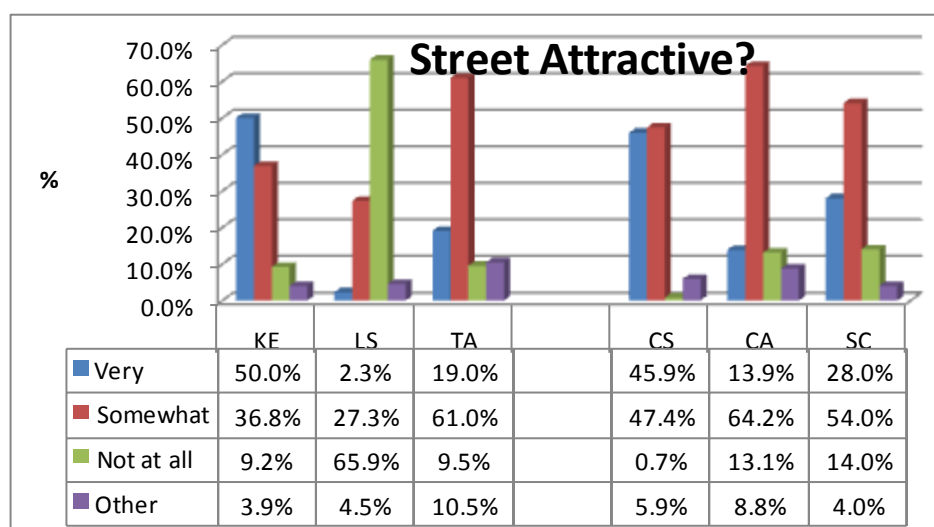


Figure 5-50. Street User’s Survey Results on Street Attractiveness

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue. Survey Respondents: KE = 75; LS = 44; TA = 105; CS = 135; CA = 137; and SC = 50.

Table 5-6

Difference in Proportions Test for Very Attractive: King Street – The Embarcadero and The Alameda

Variable/parameters	Street	
	KE	TA
Attractiveness		
p =	38	20
n =	76	105
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = 4.243$		
$z_{critical} = 1.645$		
$z_{test} > z_{critical}$, therefore H_o is rejected.		

Note. KE = King Street – The Embarcadero and TA = The Alameda.

Table 5-7

Difference in Proportions Test for Very Attractive: Castro Street and San Carlos Avenue

Variable/parameters	Street	
	CS	SC
Attractiveness		
p =	62	14
n =	135	50
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = 2.033$		
$z_{critical} = 1.645$		
$z_{test} > z_{critical}$, therefore H_o is rejected.		

Note. CS = Castro Street and SC = San Carlos Avenue.

Figure 51 summarizes in graphic form responses to the question about the convenience of each street section. The two study streets, King Street - The Embarcadero and Castro Street, were rated either the most convenient or, in the case of the latter, tied for the most convenient, in their respective cohorts. Street users in general saw the group of Small City street sections as more convenient than the Big City cohort street sections. Survey respondents gave Lombard Street the lowest proportion of very convenient responses of all six streets. Respondents rated San Carlos Avenue the least convenient of the three Small City arterial street segments.

An example of respondent views on the convenience of Lombard Street is in the following comment: “It's a thoroughfare - it's loud and full of traffic and consequently convenient in that it's not difficult to think about what your next step is... only that there's [*sic.*] all these cars in the way.”

Table 8 shows the difference in proportion test results for the first and second highest percentages of very convenient responses in the Big City street group. The hypothesis that King Street - The Embarcadero had the same or a lesser proportion of very convenient responses than The Alameda was not rejected at $\alpha = .10$ level of significance. I did not conduct this test for Castro Street with respect to California Avenue, as both had the same proportion of very convenient responses.

It is useful to note, however, that the normative value of convenience may be different from that of safety or attractiveness. While a fast food restaurant may, in fact, be a convenient choice for dinner, for example, it is typically not a healthy one. Safety and attractiveness, in contrast, do not convey this normative ambiguity. Thus, there may be a more widely shared normative basis for appraisal of streets based on these attributes.

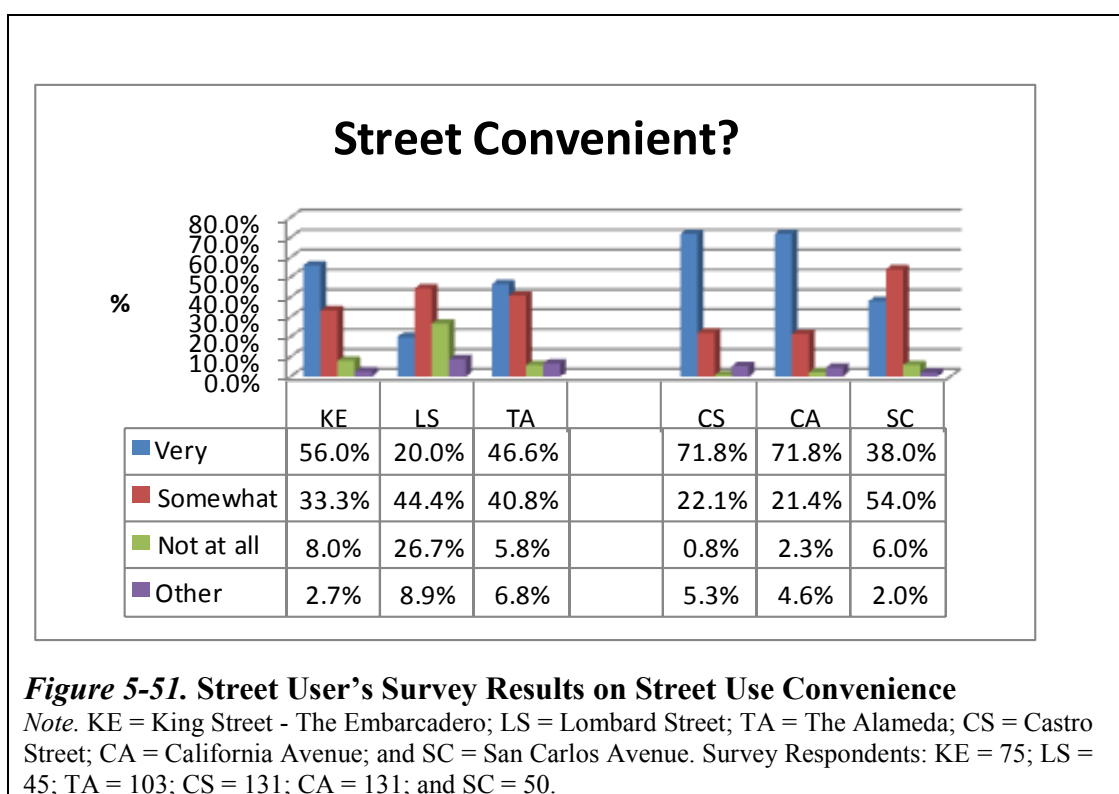


Table 5-8

Difference in Proportions Test for Very Convenient: King Street – The Embarcadero and The Alameda

Variable/parameters	Street	
	KE	TA
Convenience		
p =	42	48
n =	75	103
$\alpha = .10$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = 1.087$		
$z_{critical} = 1.282$		
$z_{test} > z_{critical}$, therefore H_o is not rejected.		

Note. KE = King Street – The Embarcadero and TA = The Alameda.

Figure 52 shows a summary of responses to the question about the amount of activity on each street segment. Survey respondents rated Lombard Street and Castro Street the most active in the Big City and Small City groups, respectively. The responses of frequent walkers differed from those who often drove to each one of these streets, however. While 76% of survey respondents who often drove Lombard Street deemed it to be very active, 53% of frequent walkers had the same opinion. In contrast, nearly the same proportion of Castro Street frequent drivers as walkers, 62% compared to 58%, judged that street as very active. The contrast in opinions of Lombard Street drivers and walkers likely reflects the dominance of automobile traffic on that street. My own impression of activity on Lombard and the other five streets as seen from the driver's seat, unlike that which I got as a pedestrian, was, influenced by traffic conditions on the street more than by liveliness of the sidewalks. Respondents did not consider either the Big City or the Small City group of streets as the more active cohort.

The Alameda received the lowest very active response of all six streets. Respondents assessed California Avenue to be the least active of the three Small City arterial street segments. One respondent expressed this opinion about the activity level on California Avenue: "California Ave is two different streets - the one during the lunch hour and the evening one. The lunch hour street is busy while the evening one is dead". A respondent to the survey about The Alameda characterized activity on that street in the following terms: "Lots of people in cars. Not a lot of pedestrians,

except shortly before and after Sharks games”. The ambiguity of the term “active” was apparent in some of the comments about how much activity there was on a given street, as in this one from a Lombard Street survey respondent: “From a pedestrian point of view, very limited activity; from a vehicle point of view - too much activity, especially at commute hours.”

Tables 9 and 10 display the results of a difference in proportion test of the two highest percentages of very active responses for each street cohort. In the Big City street group, the hypothesis that Lombard Street had the same or a lesser proportion of very active responses as King Street - The Embarcadero was rejected at an $\alpha=.05$ level of significance. More respondents to the Lombard Street than to the King Street - The Embarcadero surveys perceived their street as very busy. On the other hand, the same test conducted for Castro Street with respect to San Carlos Avenue did not result in a rejection of the null hypothesis that the former had the same or a smaller proportion of very active assessments. Thus from a statistical perspective Castro Street was not perceived as significantly busier than San Carlos Avenue.

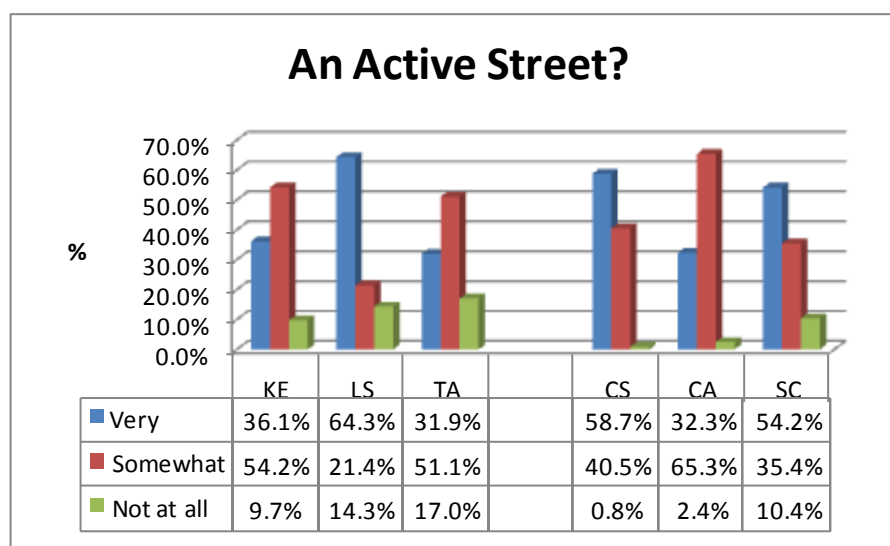


Figure 5-52. Street User’s Survey Results on Street Activity

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue. Survey Respondents: KE = 72; LS = 42; TA = 94; CS = 126; CA = 124; and SC = 48.

Table 5-9

Difference in Proportions Test for Very Active: King Street – The Embarcadero and Lombard Street

Variable/parameters	Street	
	KE	LS
Activity		
p =	26	27
n =	72	42
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = 2.715$		
$z_{critical} = 1.645$		
$z_{test} > z_{critical}$, therefore H_o is rejected.		

Note. KE = King Street – The Embarcadero and LS = Lombard Street.

Table 5-10

Difference in Proportions Test for Very Active: Castro Street and San Carlos Avenue

Variable/parameters	Street	
	CS	SC
Activity		
p =	74	26
n =	126	48
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = .372$		
$z_{critical} = 1.645$		
$z_{test} < z_{critical}$, therefore H_o is not rejected.		

Note. CS = Castro Street and SC = San Carlos Avenue.

Figure 53 displays responses to the question about the importance of each street section in the lives of survey respondents. The Alameda attracted the highest share of very important responses among Big City street segments. While California Avenue received the highest proportion of very important responses, both of the other two Small City streets, San Carlos Avenue and Castro Street were not far behind this street. In general, respondents viewed the set of Small City streets as more important to respondents than were the Big City streets. This may be attributable to the status of each of the Small City streets as a main commercial street in their community, in contrast to the position of each of the three Big City arterial

streets as one of many important commercial streets in their city. Respondents deemed Lombard Street as least important in their lives. In the words of one respondent, Lombard had little importance: “Not [in] daily life -- but I drive across the [Golden Gate]) Bridge about once a month”.

Tables 11 and 12 summarize a difference in proportion test of the first and second highest proportion of very important responses on each of the two street segment cohorts. In the Big City street group, the hypothesis that The Alameda had the same or a lesser proportion of very important responses than King Street -The Embarcadero was rejected at an $\alpha=.05$ level of significance. The same test for California Avenue with respect to Castro Street resulted in the hypothesis not being rejected at $\alpha=.05$. The fact that more users of The Alameda than King Street – The Embarcadero is likely due to a higher proportion of survey respondents who resided near The Alameda compared to the proportion the King Street – The Embarcadero respondents. Living near a street means that it is more likely to have an important affect (for better or worse) on one’s life than would a more distant street.

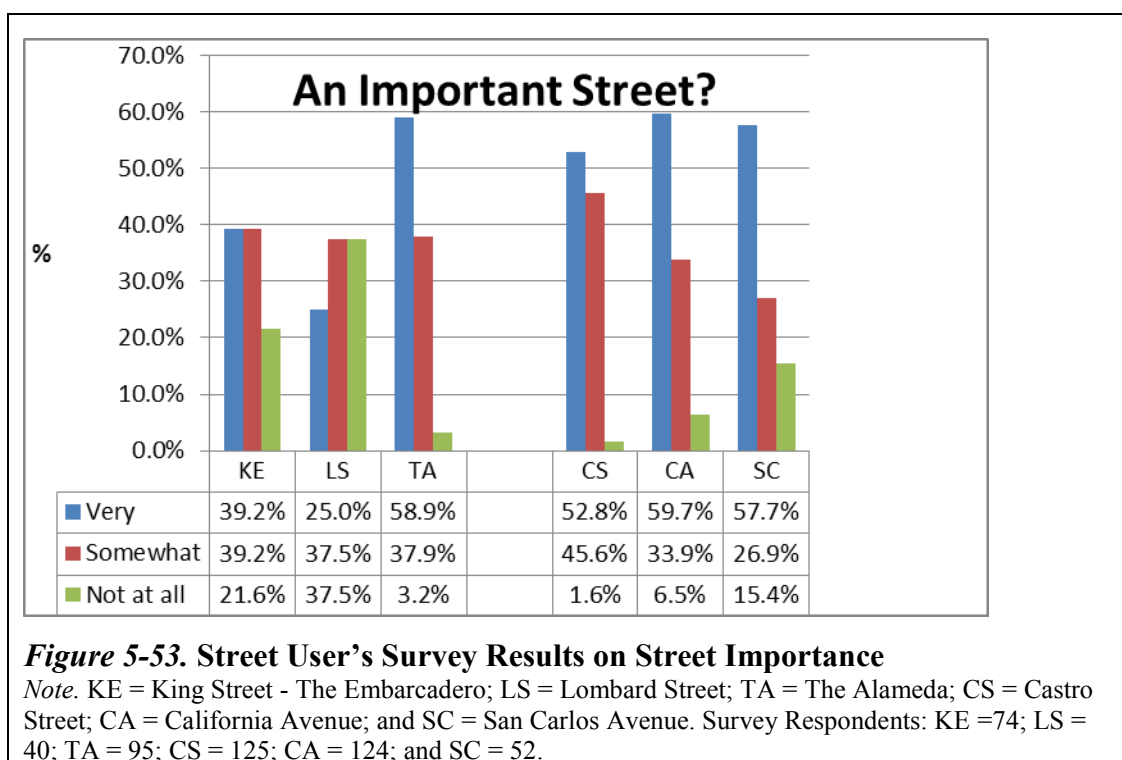


Table 5-11

Difference in Proportions Test for Very Important: King Street – The Embarcadero and The Alameda

Variable/parameters	Street	
	KE	TA
Importance		
p =	29	56
n =	74	95
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = 2.394$		
$z_{critical} = 1.645$		
$z_{test} > z_{critical}$, therefore H_o is rejected.		

Note. KE = King Street – The Embarcadero and TA = The Alameda.

Table 5-12

Difference in Proportions Test for Very Important: Castro Street and California Avenue

Variable/parameters	Street	
	CS	CA
Importance		
p =	66	74
n =	125	124
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
$z_{test} = .966$		
$z_{critical} = 1.645$		
$z_{test} < z_{critical}$, therefore H_o is not rejected.		

Note. CS = Castro Street and CA = California Avenue.

I compared the group of two test or study streets to the group of four control streets on the set of six street attributes assessed within the Street User's Survey. There were significant differences between the two groups in five of the six attributes at an $\alpha=.05$ level of significance. The only attribute not significant at this level in comparing the two sets of streets was street importance to daily life. As there may be positive and negative connotations or interpretations regarding how important something may be, it is not surprising that the difference between the test and control

streets on this dimension was not as clear. Table 13 presents the results of the significance of difference in attribute assessment between test and control streets.

Table 5-13

Fisher's Exact Test for Significance of Difference in Attribute Assessment - Test and Control Streets

Variable/parameters		Street Grouping/# and % of Respondents		
Street attribute	Level of agreement with statement	Test (KE, TA)	Control (LS,TA,SC,CA)	Fisher's 1-tailed p-value
Convenient	Very	136 (69.0%)	170 (54.7%)	<.001
	Somewhat/not at all	61 (31.0%)	141 (45.3%)	
Safe	Very	128 (64.6%)	142 (45.8%)	<.001
	Somewhat/not at all	70 (35.4%)	168 (54.2%)	
Comfortable	Very	127 (67.2%)	118 (39.3%)	<.001
	Somewhat/not at all	62 (32.8%)	182 (60.7%)	
Attractive	Very	100 (50.0%)	54 (17.5%)	<.001
	Somewhat/not at all	100 (50.0%)	255 (82.5%)	
Active	Very	100 (50.5%)	123 (39.9%)	0.0219
	Somewhat/not at all	98 (49.5%)	185 (60.1%)	
Important	Very	95 (47.7%)	170 (55.0%)	0.1221
	Somewhat/not at all	104 (52.3%)	141 (45.0%)	

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Street user likes and dislikes.

I also asked respondents to the surveys of street users on each street about what they liked and disliked about the street.⁸³ I asked respondents to each of the six street user's surveys open-ended questions about what they liked and disliked about the streets. While responses were wide-ranging, there were also clusters of references to particular topics. I have summarized these replies below for each street segment with quotations to add texture. Total responses varied by question within each of the street surveys, as not all respondents in each street user's survey offered an opinion about each question.

⁸³ A transcript of responses pertaining to each street is available at the URDMS Curtin University research data repository.

King Street - The Embarcadero: likes/dislikes.

The most frequently reported features appreciated by the 59 King Street - The Embarcadero respondents were pedestrian access and facilities (26), availability of restaurants, shops, and stores (20) and access to and availability of public transport services (19). Illustrative statements of what respondents liked about this street section include the following: “Ballpark, wide sidewalks, rail transit, street trees, mixed-use buildings, tall buildings”; and “Wide median with streetcar, wide sidewalk, new development, the ballpark, restaurants, the bike lane on Embarcadero.” Respondents also indicated an appreciation for the streetscape details and/or architectural scale of buildings on the street (9), the views from the street (9) its cleanliness (9), and the trees and landscaping along King Street - The Embarcadero (8). Survey respondents expressed satisfaction with the street as a place for travel, commerce, recreation, and aesthetic enjoyment. In summary, King Street - The Embarcadero elicited approval for being a street created for and serving multiple purposes, including but well beyond motor vehicle transport. As one respondent observed, “The scale of buildings seems appropriate. The street is interesting and lively. There is plenty of room on both sides of the sidewalk.”

The most frequently reported aspects disliked by the 62 King Street - The Embarcadero respondents who had negative comments were the speed of motor vehicle traffic (13), pedestrian crowding and traffic congestion on baseball game days (8), and not enough commercial development (6). Illustrative of what respondents disliked about this street section are these remarks: “The street is very wide and hard to cross. Traffic is fast. Massive traffic on King when there's a game at the park” and “Too crowded to transverse on game days at ATT.” Some of the dissatisfaction is traceable to the multiple tasks assigned to this street: to host a major league sports venue, as well as serve as a conduit for traffic entering and exiting the I-280 freeway to the south. On balance, the statements of likes and dislikes depict a street much admired yet not quite meeting all the great expectations put on this young boulevard.

Lombard Street: likes/dislikes

The aspects of Lombard Street that drew the most praise from the 31 survey respondents who provided comments were the convenience or efficiency of the street for drivers (12) and the variety of shops, stores, and restaurants (6). Driving on

Lombard Street can be fast and predictable. One Lombard Street respondent summarized the utility of Lombard Street to drivers by noting that, “It's a main artery where taking side streets would be a detour and would take much longer, unless that's where your destination is.” Another asserted:

What I like about Lombard is that it keeps visitors to SF from the north out of my neighborhood. It is good at channeling cars into SF and I must admit I use it too in my car to get to other neighborhoods, such as downtown, Pacific Heights and the 101 south freeway.

The overall impression given by respondents, however, is that of a street not loved for its own virtues as a place in which to linger and enjoy, but a travel route recognized for dutifully discharging its job as a traffic artery.

Conversely, of the 40 respondents who expressed displeasure about one or more attributes of Lombard Street, many thought that the street had too much motor vehicle traffic (17) and/or was unsafe and/or uncomfortable for pedestrians to cross (14). Illustrative of these comments are the following: “It's basically an off ramp from 101S. Everyone driving on Lombard is on their way through - originating somewhere else and ending up somewhere other than Lombard” and “It's too fast, cars don't make complete stops, it's very dangerous on foot or bicycle, and it's ugly. Can't we have some flowers in the medians or something? Some traffic calming?” Other dislikes included building architecture and/or the land uses along the street (8), as well as the opinion that the street is noisy (7) and ugly (7). Respondents stated their displeasure about various aspects of Lombard Street both emphatically and passionately. In the words of one respondent:

The street is like a freeway, too crowded with cars, buses and commercial vehicles. Patronizing the businesses is not attractive because it would be difficult to get out of moving traffic and find a parking space. The buildings are not very attractive, just plain rectangular architecture mostly with very little greenery.

The overall verdict on Lombard pronounced by street users who contributed narrative comments was emphatically negative. For many respondents, this street section exemplifies all that is objectionable in the description of such streets as “sewers for traffic” (Newman, 1998, p. 307).

The Alameda: likes/dislikes.

The mix of shops, stores, and restaurants (52), as well as the ongoing improvement in such services, along with the future re-development potential of the street (37) were the two attributes of The Alameda most appreciated by the 93 respondents who offered opinions on what they liked about the street. The architecture (26), tree canopy (24), and access from nearby neighborhoods (21) of The Alameda also drew praise. Respondents expressed these themes in the following comments:

I enjoy the history of the street and the local businesses. The older buildings are interesting and there is a real neighborhood feel at a few locations.

It's close. It has some cool old architecture and a kind of 'out of time' feel to it. It's also changing so there's a narrative unfolding.

The sycamore trees help create a pleasing streetscape and the juxtaposition of the old and new buildings make it an interesting walk.

I like the mix of architectural styles and the emerging retail and restaurant scene.

Many of the comments in praise of The Alameda express pride in what the street once was and hope for what the street may yet become. In the words of two respondents: "It's a grand old lady of a street" and "It is an historic street that has the potential to be a true destination in San Jose."

On the other hand, 95 survey respondents had a myriad of complaints about The Alameda. Principal among these were unsafe and uncomfortable conditions for pedestrians (31), motor vehicle traffic that was too fast (23), derelict buildings or empty lots (21), and not enough variety in goods and services available on the street (17). The following comments illustrate these concerns about The Alameda:

It's not walkable at all. A lot of the buildings are in disrepair and the road condition is terrible.

Instead of a neighborhood friendly "main drag" The Alameda is also a mini freeway for traffic.

The traffic! Cars are way too fast. There are no safe pedestrian crosswalks.

I don't like the lack of services, restaurants, and nightlife on the Alameda.

Survey respondents were also unhappy about individual businesses and/or the composition of the business mix on The Alameda (17), undesirable people and/or fear for personal security (14), the volume or general character of motor vehicle

traffic (13), motor vehicle parking provision (12), and pavement condition (12). The criticisms leveled at The Alameda were multi-faceted. Many respondents expressed variations on a common theme of a street neglected, consigned to use mainly as an artery for motor vehicle traffic coming from and headed elsewhere. As a summary characterization, street user comments reflected a yearning for restoration of The Alameda as a place as well as a link.

Castro Street: likes/dislikes.

A striking 80 of the 123 respondents who expressed what they liked about the street cited the variety of restaurants or mix of goods and services available on the street, or both. Respondents praised other attributes, including the pedestrian-friendliness or “walkability” of Castro Street (29), the street’s trees and/or landscaping (25), the proximity of Castro Street to their own neighborhood (21), the availability of outdoor dining opportunities (19), and the liveliness and amount of activity on the street (17). Survey respondents also cited various functional features of the street that contributed to its pedestrian-friendliness, such as the sidewalks, crosswalks, and pedestrian crossing signal heads (24). Castro Street respondents were often emphatic and enthusiastic in their appreciation for the street. Examples of statements that reflect these views and the tones in which they were expressed are as follows:

Lively mix of shops, restaurants, cafes, and public spaces (e.g. City Hall Plaza); independent shops with reasonable prices; informal ambience; outdoor seating and high pedestrian traffic create lots of opportunities for people watching; narrow streets and frequent crosswalks make it easy to navigate on foot; parking situation is usually not hard to find. I love the bookstores.

The sidewalks are wide and there is just one lane of traffic each way, there are easy places to cross it, and there are quite a few trees and other plants there. There is an interesting mix of people on the street at different times of day, and a reasonable range of stores.

It's a pedestrian-oriented street -- quite rare in the South Bay. It has a variety of restaurant choices, and they're not big national chain restaurants. The fine grain of the buildings; the variety of architectural styles; buildings that come right to the sidewalk and have windows giving a view to what's inside; all of that makes it interesting to stroll along Castro.

I love the walkability, the shops, the bookstores, the coffee shops, the restaurants, the civic center, the outside eating where you can watch people go by, that it is walkable from my house (ok, I moved here for that exactly). It's focused on pedestrians and creates a sense of community. I love all the outdoor restaurants, and the buffer between people and cars created by that seating (as well as the wider sidewalks). I love the variety of restaurants and some of the shops, and walking around at night when it's crowded. It's one of the few streets on the Peninsula that has a sense of community.

Castro Street respondents' dislikes expressed their displeasure within a somewhat narrower range of topics, including the need for more variety in the mix of businesses (43), an antipathy to a particular business or land use or a particular block along the street (28), the amount of motor vehicle traffic (24), and complaints of one kind or another about parking (18). Although respondents expressed negative feelings in a few instances with more fervor than positive ones, in general the criticisms expressed by survey respondents did not have the same emphatic quality as the enthusiastic praise given to the street. The quotations below illustrate the representative content and tone of the dislikes articulated by respondents:

Too few retail stores, no grocery (except one small specialty grocery).

A bit too much traffic. Would be nice if the outdoor dining didn't have to have cars go by.

The parking - it's attractive, but the trees really limit the number of spots to park. The south end is fairly bland - from Mercy, after the civic center, to El Camino.

Sidewalk is often crowded when we go. Outside dining from California to Evelyn is not comfortable for us because of the noise and odors from the close traffic.

California Avenue: likes/dislikes

Nearly mirroring Castro Street respondents, 76 of the 122 California Avenue respondents who expressed what they liked about the street noted the diversity of restaurants or mix of goods and services along the street. The most appreciated facet of California Avenue, cited in one form or another by 35 respondents, was the neighborhood main street ambience or "feel" of the street. The availability of a farmers' market and other street fairs (31), convenient parking (27), lack of vehicle traffic and/or crowding (22), presence of local rather than national chain stores (21),

proximity of California Avenue to nearby neighborhoods (17), and its unpretentiousness (15) also elicited approval. The respondent comments below give a flavor for these opinions:

It's like a small town main street and there's not a lot of traffic. There are shops that provide useful products and services.

Parking is fairly easy. The farmers' market is great.

It has a small town feel to it -- it's more like Palo Alto used to be.

I like the independent businesses (Izzy's bagels, Country Sun, Shoe shop, Green cleaners) and the new Sunday Farmers Market. We enjoy the restaurants occasionally. It is wonderful to walk or bike to a local shopping area.

I like the combination of service-oriented places, like grocery stores, dry cleaners, etc. and restaurants. I like that most businesses are not large chains. I like its small scale, and ease of access - as I live nearby. Also, the shops and restaurants that I frequent are very good, and not full of the pretention of downtown.

The most frequent dislikes among the 111 California Avenue survey respondents who registered complaints were about the business mix (37), need for an update to the buildings and street front (22), quality of public art (20), parking (20), and inadequacy of trees and other landscape features (13). The parking complaints ranged from insufficiency of time allotted to parking or space available in given locations, to the difficulty and/or danger of on street diagonal parking. Some respondent comments that illustrate these concerns follow:

Too many nail salons and hair salons. Wish it had more variety (book store, specialty shops, bakery, coffee shops like Coupa Cafe, toy store). Wish it looked better too.

It's a bit dated and just needs a little TLC. Light fixtures, old concrete planters and kiosks, and old cheap bike racks. Need more plants and growies⁸⁴ and less concrete.

The diagonal parking is difficult for drivers and dangerous for bicyclists. Buildings aren't charming, no unified feeling, feels dirty-ish, pretty hard to find 'parking in front of the store'. The store front displays aren't great so

⁸⁴ The term "growies" used by this respondent referred to flowers, trees, bushes, and similar natural landscaping features.

there's no delight in walking down the street and being drawn in, in fact there are some 'weird' stores on California like a couple of office buildings and the computers store with the covered up windows. Many stores and shops there feel worn out or second best even if we still go to them.

The so-called "Art" is ugly: Big face made of metal wire, a tree trunk carved to look like a screw, the running doll with a face in her belly.

The presence of parking as both something appreciated and criticized by survey respondents reflects the deceptive complexity of a seemingly straightforward concept. The location (close to or further away from a favored destination), type (on-street, off-street surface lot, or structure), design (parallel or angled), and availability of the type of space in the location and time period desired are all factors in the consumer assessment of parking adequacy⁸⁵. California Avenue street users, like those on The Alameda, find much to love about their street and see its potential as a community main street, although many still decry its present condition.

San Carlos Avenue: likes/dislikes.

The landscaped medians (12), landscaping and street trees (6), stores and restaurants (6), sidewalks (6), tree lights at night (5), and street width (5) were street attributes that drew the most frequent favorable comments from the 43 San Carlos Avenue respondents who expressed their views on what they appreciated about the street. In contrast to both the Castro Street and California Avenue street user's surveys in which the mix of stores and restaurants was by far the most admired street characteristic, land use mix was mentioned with only a third of the frequency of landscaping and street trees by the San Carlos Avenue respondents. The following statements illustrate the most popular attributes of San Carlos Avenue.

I like the restaurants and drug store. I like the trees down the center of the street. I like that it is near the train station and is surrounded by residential neighborhoods (making it easy to get there without driving). I like that there aren't big parking lots in front of the stores - feels more quaint.

All the restaurants, the lit trees in the center divide.

I appreciate the multiple lanes to accommodate heavy traffic and the bike lanes. I also like the efforts at landscaping the median near downtown.

⁸⁵ For excellent treatments of the complexities of parking supply, demand, and design see both Shoup (2005) and Litman (2006).

The most frequently mentioned dislikes of the 43 San Carlos Avenue respondents who answered this question were that the street was too difficult or dangerous for pedestrians to cross (11), vehicle speeds were too high (10), the street was too wide (7), too congested (6), and lacked continuous bicycle lanes (5).

Comments illustrating these views are as follows:

It's too wide, some folks drive too fast or run the lights, or don't look when turning right, so they don't see pedestrians in the cross walk - I live at Holly and Walnut and frequently walk across San Carlos Ave.

I don't like how fast the traffic goes. The bike lanes end halfway down the street. For a downtown street, I don't like that Longs is surrounded by a parking lot - this is more appropriate for a street like El Camino.

I don't like the width, the traffic volume, and the difficulty moving into the left lane.

There was a decidedly mixed verdict given to San Carlos Avenue. While some respondents appreciated the traffic function of the street and many liked that street's trees and landscaping, there was more fervor in the criticisms of San Carlos Avenue as too dominated by motor vehicles.

The street user's survey asked respondents about how they would improve about their respective streets and what additional comments they wished to offer. Not surprisingly, they offered a wide range of ideas.⁸⁶

Business survey.

This section presents a summary of survey responses of business people to questions about the business environment and level of activity on each street. This summary includes tabulations of Business Survey respondent comments about what aspects of each street they liked and disliked illustrated by quotations from respondents. As may be expected, the business people surveyed had a variety of perspectives about the streets on which they had a commercial interest. In general, the accessibility of their enterprises to customers and clients was an important issue for them, as was the appearance of the street. Like other street users, business survey respondents were also concerned about street safety and the ease of street use.⁸⁷

Business assessment of street attributes.

⁸⁶ A complete transcript of responses to both questions is contained in the URDMS Curtin University research data repository.

⁸⁷ A transcript of all written comments of the Business Survey respondents is accessible at the URDMS Curtin University research data repository.

Business Survey respondents deemed King Street - The Embarcadero and Castro Street to have the best business environment in their respective cohorts. The difference between the share of Excellent/Good compared to Fair/Poor assessments given by Castro Street respondents and the next most positively assessed Small City street was significant at an $\alpha = 5\%$ level. This means that there is a statistically significant difference in the business environment on Castro Street in contrast to San Carlos Avenue. By logical extension this also means California Avenue too since that street is less well rated as a business environment than either of the other two. In contrast, the difference in these proportions for King Street - The Embarcadero and the next most positively assessed Big City street, Lombard Street, was not significant at this level. Figures 54 and 55 summarize findings for each street cohort. Tables 14 and 15 reveal the results of statistical significance testing for each subset.

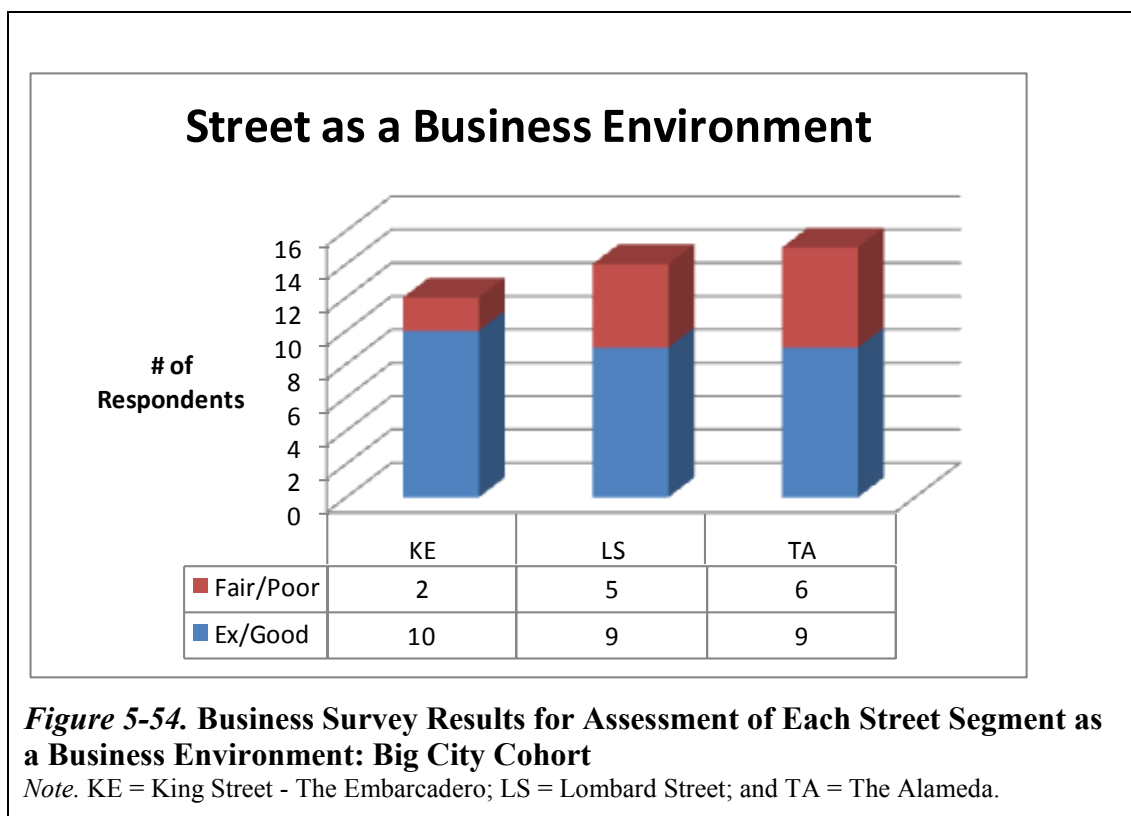


Table 5-14

Fisher's Exact Test for Street as a Business Environment: Excellent/Good Compared to Fair/Poor Assessment of King Street – The Embarcadero and Lombard Street

Variable/parameters	Street	
	KE	LS
Excellent/good	10	9
Fair/poor	2	5
$\alpha = .05$, 1 –tailed test		
$H_0 = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
Fisher's P = .2609		
Fisher's $P > \alpha = .05$ therefore H_0 is not rejected.		
Note. KE = King Street – The Embarcadero and TA = The Alameda.		

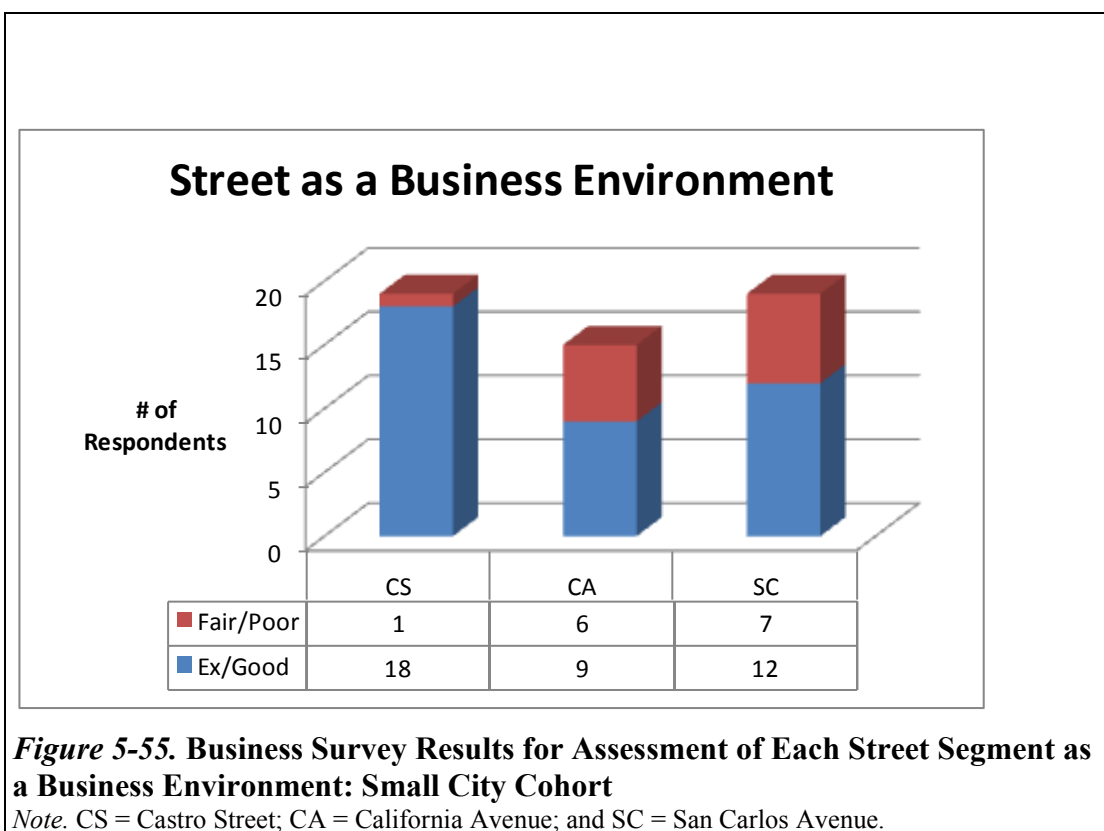


Table 5-15

Fisher's Exact Test for Street as a Business Environment: Excellent/Good Compared to Fair/Poor Assessment of Castro Street and San Carlos Avenue

Variable/parameters	Street	
	CS	SC
Excellent/good	18	12
Fair/poor	1	7
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
Fisher's $p = .0211$		
Fisher's $p < \alpha = .05$ therefore H_o is rejected.		

Note. CS = Castro Street and SC = San Carlos Avenue.

There was a significant difference at an $\alpha=.05$ level between the two test or study streets and the four control streets in appraisal of the business environment. While about nine out of every ten respondents doing business along one of the two test streets judged the business environment to be excellent or good, just six out of every ten respondents on the control streets made that judgment. Figure 56 and Table 16 summarize these findings.

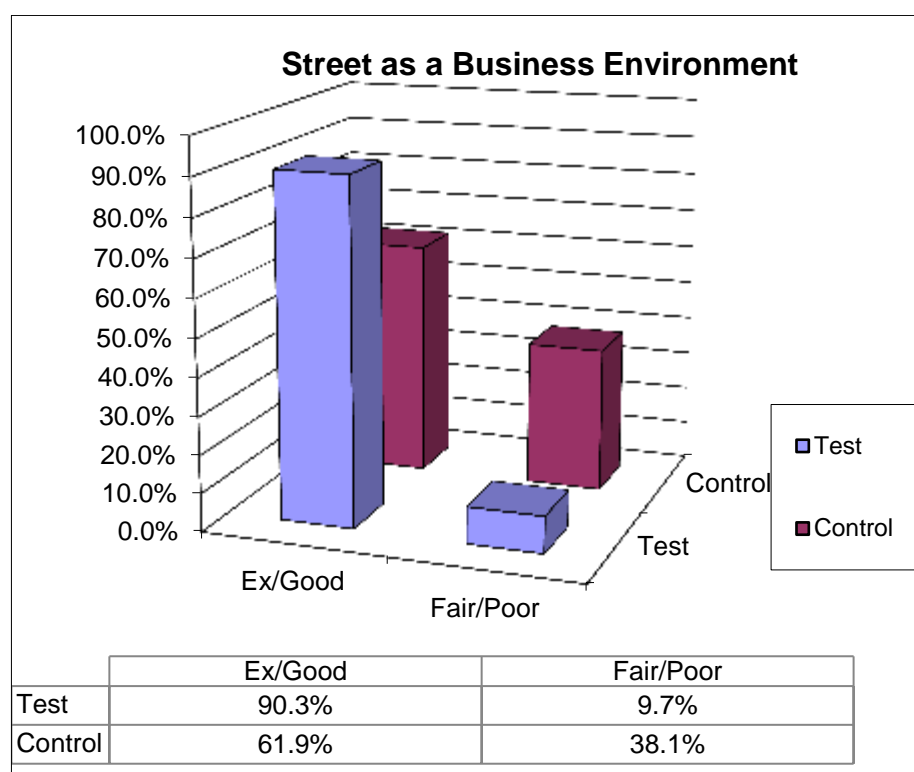


Figure 5-56. Business Survey Results for Assessment of Test and Control Street Groupings as Business Environments

Note. Test streets: King Street – The Embarcadero and Castro Street. Control streets: Lombard Street, The Alameda, California Avenue, and San Carlos Avenue.

Table 5-16

Fisher's Exact Test for Street Activity: Excellent/Good Compared to Fair/Poor Business Assessment of Test and Control Street Groups

Variable/parameters	Street Group	
	Test	Control
Excellent/good	28	3
Fair/poor	39	24
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
Fisher's $p = .003$		
Fisher's $p < \alpha = .05$ therefore H_o is rejected.		

Note. Test streets: King Street – The Embarcadero and Castro Street. Control streets: Lombard Street, The Alameda, California Avenue, and San Carlos Avenue.

Business survey respondents on the six streets gave a mixed verdict on perceived activity level of the streets on which they did business. While respondents assessed Castro Street as the most active Small City street, King Street - The

Embarcadero was deemed less active than The Alameda. The difference in perceived activity, measured as proportion of very active compared to somewhat active and not at all active responses, between Castro Street and its nearest competitor, California Avenue, was statistically significant. That between King Street - The Embarcadero and The Alameda, however, was not. Figures 57 and 58, as well as Tables 17 and 18, show these findings.

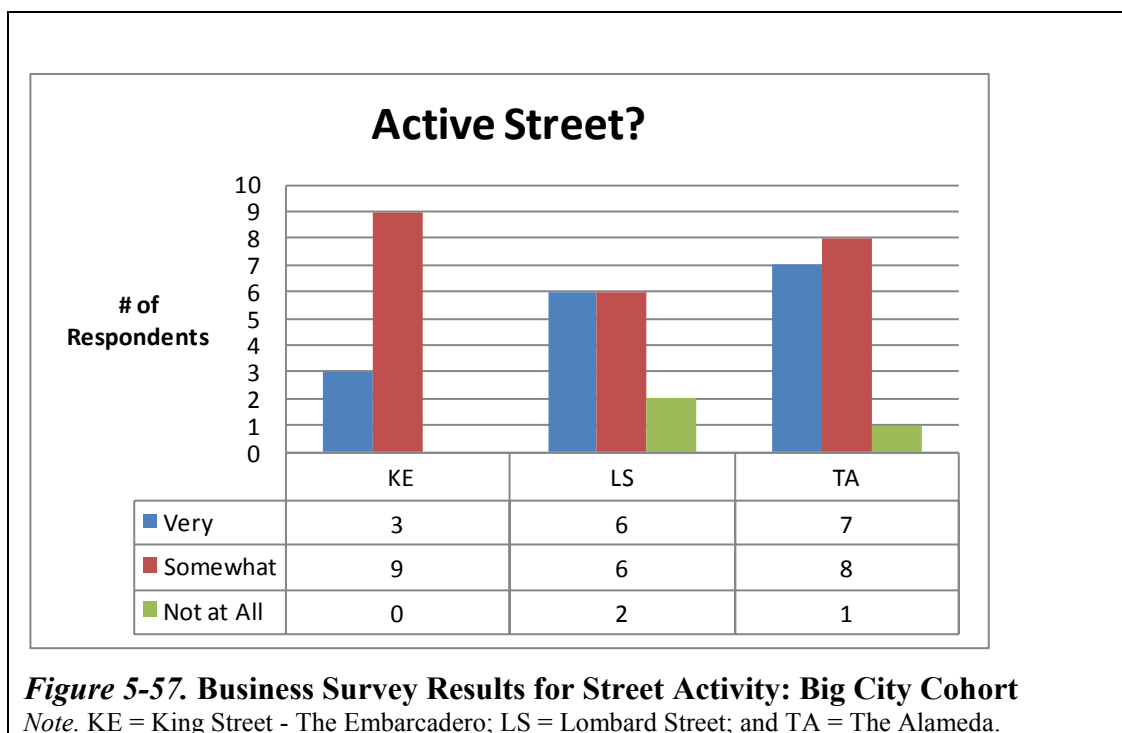


Table 5-17

*Fisher's Exact Test for Street Activity: Excellent/Good Compared to Fair/Poor
 Business Assessment of King Street – The Embarcadero and The Alameda*

Variable/parameters	Street	
	KE	TA
Excellent/good	3	7
Fair/poor	9	9
$\alpha = .05$, 1 –tailed test		
$H_0 = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
Fisher's $p = .2676$		
Fisher's $p > \alpha = .05$ therefore H_0 is not rejected.		

Note. KE = King Street – The Embarcadero and TA = The Alameda.

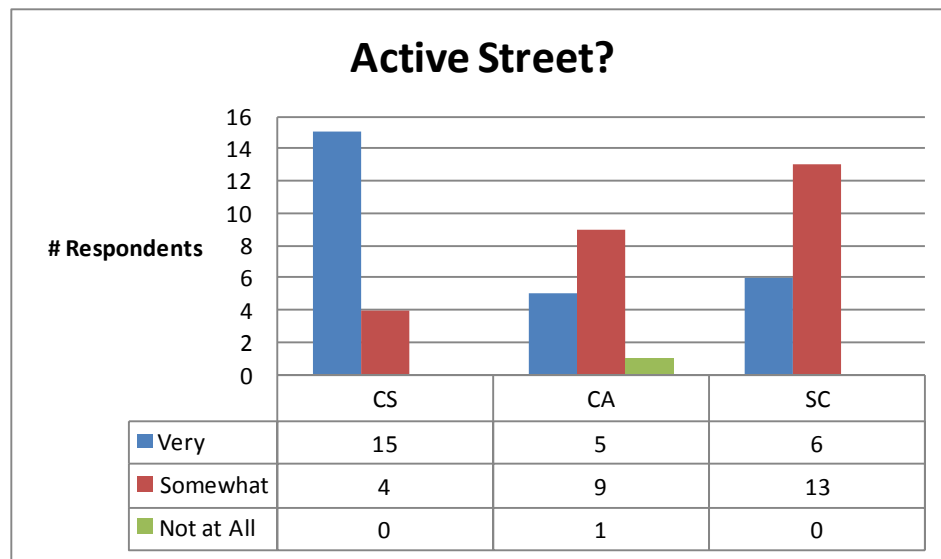


Figure 5-58. Business Survey Results for Street Activity: Small City Cohort

Note. CS = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

Table 5-18

Fisher's Exact Test for Street Activity: Excellent/Good Compared to Fair/Poor Business Assessment of Castro Street and California Avenue

Variable/parameters	Street	
	CS	CA
Excellent/good	15	3
Fair/poor	5	10
$\alpha = .05$, 1 –tailed test		
$H_o = p_a - p_b \leq 0$		
$H_a = p_a - p_b > 0$		
Fisher's $p = .0094$		
Fisher's $p < \alpha = .05$ therefore H_o is rejected.		

Note. CS = Castro Street and CA = California Avenue.

Likes and dislikes of business survey respondents.

I also asked respondents to each of the six business surveys open-ended questions about what they liked and disliked about the streets. As with the street user's survey, the business survey responses covered a wide variety of topics. Some topics appeared more often than did others. The text below summarizes responses, highlighted by quotations from respondents.

King Street - The Embarcadero Business Survey respondents most appreciated the views (4) from this street as well as the public transport service (3) available to their customers and employees. The following comments captured these sentiments: “Beautiful - water views, Muni line design, palm trees” and “Open, airy, clean feel; streetcar access; water view.”

The main topic of displeasure was the inconvenience caused by frequent special events like baseball games and foot races (3). These views are represented in these quotations from Business Survey respondents describing what they disliked about King Street - The Embarcadero: “Subject to all special event scheduling there can be street closures, re-routing, impossible parking (Giants games, Marathon, Bay to Breakers, etc.). One-hour (not two-hour) meters mean our customers are always short on time” and “Ball games, special events crowds, traffic, closures.” Business survey respondents were in broad agreement with other King Street - The Embarcadero street users in applauding transit provision and views while being dissatisfied with special events traffic.

The most frequently mentioned positive comment about Lombard Street was the visibility (4) available to businesses on the street. One respondent defined this attribute as simply “a lot of exposure for business.” Respondents offered reciprocal, negative views on the amount of motor vehicle traffic and/or the speed of motor vehicles on the street (7), the dearth of foot traffic (3), and parking difficulties (3). The following comments illustrate these complaints:

Traffic is too fast for retail business.

There isn't enough foot traffic on Lombard. Most people are either driving into or out of the city so it's hard to stop, go into a business and continue.

Parking is also a big problem.

As was the case with King Street - The Embarcadero, Lombard Street business survey respondents were in broad agreement with the street user's survey respondents. Both decried the dearth of pedestrians, the amount and/or speed of motor vehicle traffic, and parking conditions. On the other hand, Lombard Street business people, but not their customers and the rest of those who responded to the street user's survey, valued the exposure provided by sheer numbers of people passing their establishments in motor vehicles.

The Alameda Business Survey respondents were most positive about the recent improvements on the street and/or its potential for the future (7), its proximity

to downtown San Jose (4), and accessibility to freeways (4) or to public transport (3). The comments below reflect these views:

It is a developing area. A lot of the old businesses are moving out and higher-density projects are coming in. A revitalization of the area is occurring.

It is easily accessible from Highway 87 via Julian and Highway 880. It has proximity to downtown and the Pavilion. It is a historic street and is rapidly improving. New restaurants are coming to the area including a Whole Foods at the corner of The Alameda and Stockton. I like the future of The Alameda.

On the other hand, respondents disliked motor vehicle traffic volume and or speed on the street (4), the quality of one or more businesses (4), and the quality of one or more buildings (4). The following remarks illustrate these concerns:

Fast traffic - hard to build a sense of community - but there are people who try.

Appearance looks old and run down. No proper lighting. Poor visibility.

Need to increase foot traffic for survival of service businesses like drug stores, convenient stores and restaurants.

Consistent with the other two arterial street sections, business people and other users of The Alameda agreed on key points. These included the up and coming nature of the street, the spotty character of existing land uses, and the nature of motor vehicle traffic on the street.

Castro Street Business Survey respondents appreciated the variety of restaurants (6), the foot traffic on and/or walkability of the street (4), and its cleanliness (3). The following statements exemplify these views: “Main strip in downtown Mountain View creates lots of new customers; many restaurants which all seem to be very successful; variety of different restaurants and businesses as well as lots of foot traffic”; and “Clean; a lot of restaurants.”

Respondents most frequently cited as dislikes parking issues (4) and the number of restaurants. These were expressed by such comments as “Too many restaurants have created an ‘in an out’ environment” and “Parking is difficult for employees and customers; not enough retail shopping.” Once again, business people and street users agreed about the essential themes. For Castro Street, these include an appreciation for its commercial variety, the liveliness created by all the foot traffic alongside and across the street, and – at least for some – frustration with some aspect of parking provision.

The California Avenue business people who responded to the survey liked the vibrancy (5) and sociability (4) of the street, as well as its business mix (3) and parking provision (3). The following statements offer these commendations:

Mixture of business and local stores. Good parking. Safe. Vibrant but not overcrowded like University. I like the width of the street and the island down the middle with plantings. Decorative street lighting is pretty. Street is well lit.

Light auto traffic. Lots of nice people during the day, especially lunchtime.

Good street 'vibe' during the day.

Survey respondent dislikes included homeless or derelict people (5), parking problems (5), and concerns about types of businesses on the street (3). Comments like these reflect these criticisms:

Homeless people camping out both in front of and inside of businesses. Lack of adequate parking for employees. Large number of empty storefronts.

Large number of businesses that are not open after 7 PM.

Needs more upscale stores;

a little too shabby compared to University Ave.

The community feeling and the commercial variety of California Avenue resonated with both business people and residents. Both groups expressed concern about run-down conditions along the street and both had intra-group differences of opinion about how good or poor were the parking provisions.

Business people along San Carlos Avenue expressed an appreciation for the visibility and exposure of businesses on the street (7), the ease of parking (3), the provision of parkland and/or landscaping (3), and the cleanliness of the street (3).

The following remarks show appreciation of these aspects of the street:

Very open. Great parking for visitors. Beautiful park and preservation of nature. I like the local feel of it, especially closer to Laurel & El Camino. It is a very clean street

Easy access. Plenty of parking, good traffic flow.

The most frequently mentioned dislikes of San Carlos Business Survey respondents were parking problems (6), trees and/or landscaping on the street (3), and lack of foot traffic (3). The statements below summarize some of these concerns: "Slow foot traffic; not enough events; no night life; not enough parking" and "trees intrude on store fronts too much."

San Carlos Avenue business survey respondents did not agree with each other. They also disagreed with comments of other street users. Business people disagreed with each other about the merits or demerits of both parking and landscaping provisions. Like Lombard Street business people, however, they were unambiguous in praise of the exposure provided their businesses by passing motor vehicle traffic. Respondent comments in both the business survey and the street user's survey, however, reflected dissatisfaction with the lack of pedestrian traffic on the street.

The more favorable assessment of the test streets compared to the control streets given by business people conforms broadly to the results reported by Hass-Klau (1993) for various streets in German cities and Drennen (2003) for San Francisco's Valencia Street. In these cases, as with both King Street - The Embarcadero and Castro Street, business people were positive in their evaluation of the effects of re-designs that redressed the former motor vehicle traffic domination of street life.

Focus groups.

The focus group sessions conducted for each of the six streets in this research provided the kind of texture and detail only available in an interactive setting. While all sessions had the same initial set of topics to discuss, each focus group conversation followed a unique course as discussion proceeded.

The King Street - The Embarcadero conversation.

The tenor of the focus group session for King Street - The Embarcadero was decidedly positive. The most frequently referenced positive themes were good walking conditions (4), enjoyable views (4), commodious public spaces (3), the activity level on the street (2), and the convenience of public transport (2). The two negative themes mentioned more than once were the need to improve public transport services and connections (2) and dislike of abandoned piers and warehouses on the northern reach of the street section (2). The following excerpts from the focus group transcript give a flavor for the discussion:

You have so many moments of breathtaking views on either side: the Bay Bridge, the Bay, and the downtown buildings.

Muni on King Street and The Embarcadero is a very important, very convenient transit link.

(There is) a lot going on; people running, people mingling. That all feels pretty good.

The traffic moves on the Embarcadero; at the same time you don't feel menaced by all that traffic.

When the Embarcadero Freeway was here, the whole neighborhood was about the freeway; that was it.

The re-design opened up the whole district.

It's a little scary sometimes crossing (the street); so many cars.

We've got traffic going all around us and we barely notice it.

The Lombard Street conversation.

In contrast to that for King Street – The Embarcadero, the Lombard Street focus group conversation had a decidedly negative tone. The most frequently mentioned themes that expressed complaints about the street and its environs included poor pedestrian conditions and/or the need for wider sidewalks (9) too much traffic and or motor vehicle speeds that were too high (5), poor street maintenance (2), and unsafe and/or inconvenient curbside parking (2). On the positive side, Lombard Street won commendations for good pedestrian signal equipment at intersections (2). The following quotations from the focus group session give texture beyond the simple theme counts:

I avoid Lombard Street if at all possible.

Lombard Street is not walkable to any destination on it

It's like a freeway.

It's fairly deserted as a walking street.

Lombard Street is in the middle of several neighborhood communities; there is potential for Lombard, but something would have to be done about the traffic.

The countdown (pedestrian) signals have reduced the red light running.

The Alameda conversation

The focus group discussion for The Alameda had mixed results. Favorable themes included the availability of a range of destinations within walking distance on the street (4), the building architecture on the street (2), the potential of The Alameda (2), and the comfort in using the street (2). Unfavorable themes included traffic speeds (2), the architecture along the street (2), discomfort in using the street (2), the

need to re-route traffic away from the street (2), and vacant buildings and/or gaps in the street front (2). The quotes below illustrate the character of this conversation:

I can get to most anything I like on The Alameda without using a car, as long as I don't bike on The Alameda.

Most of the time I try to avoid walking on The Alameda; I walk in the (nearby) neighborhoods until I'm close to where I want to be, then cut into The Alameda.

As long as The Alameda is the main thoroughfare between downtown San Jose and the freeway it will be untenable for any other purpose.

There is phenomenal potential for this street.

The width of the street is the core problem; that accommodates all the traffic. The problem with the traffic on The Alameda is that it doesn't help the businesses; it's just going through.

One of the great things about this street is the wide sidewalk; that's fairly unusual.

The Castro Street Conversation

The Castro Street focus group conversation was mostly on an affirmative note. The most frequent themes expressing appreciation for the street included the pedestrian environment (8), the restaurant choices (4), the convenience to nearby neighborhoods (2), the "boulevard" (wide and landscaped median) section of the street (2), and the proximity of rail passenger services (2). Conversely, dissatisfaction was expressed about too many restaurants (4), too many cars and/or cars too close to sidewalk café seats (4), sidewalk crowding (3), need for more variety in restaurants (2), parking (2), bicycling conditions (2), and the need for a movie theatre (2) or a grocery store (2). The quotations that follow highlight some of these sentiments:

I have never had any problems walking across Castro Street. I don't feel vulnerable walking along Castro Street, even at night.

It's incredibly easy to cross Castro Street.

There are so many people out there (on Castro Street), there are so many restaurants; in that respect you feel safe on the street.

Whenever you have something to get done, you head to Castro Street.

I see Castro Street as the backbone of a great small city.

The median strip changes everything on the street, the aesthetics, the feeling, the grass, the trees; it transforms the street and creates calmness.

I would say that safety at best is medium because of the volumes of people and the volumes of cars.

As a bicyclist, I find Castro Street not safe; it's just too tight.

You're shoulder to shoulder with cars; it's too close to cars.

The California Avenue conversation

The California Avenue focus group participants were mainly, but not entirely, positive in their comments about the street. The architectural scale (3), prevalence of independent stores (2), availability of rail and bus transit nearby (2), and sidewalk cafes (2) were the most frequently referenced among the positive themes. Too many motor vehicle travel lanes and/or excessive street width (5), being too "car friendly" (2), and the lack of a continuous median (2) were the most frequent themes with negative connotations. The statements that follow illustrate some of these themes:

I love the fact that there are independent stores on this street.

I appreciate the scale; not surrounded by high rises.

What I love is being able to eat out front, the cafes.

I like that within walking distance I have buses and trains.

I'd like to see it more vibrant with more people coming here.

We don't need quite as much street; we need more sidewalk.

The street is too car friendly, less pedestrian friendly and less bike friendly.

I'd like to see a better mix. I think that this has to do with the street configuration. This is a huge, wide street, so that you just want to speed.

The San Carlos Avenue conversation.

Nearly all of the San Carlos focus group session discussion was critical of the street. The most frequent negative themes raised related to pedestrian safety concerns (4), motor vehicle speeds (3), the street section being too wide in its western reach (2), bike lane discontinuity (2), the hazard in transition from four to two through lanes in the easterly reach (2), the need for wider sidewalks (2), and an insufficiently diverse land use mix (2). This group produced some of the most quotable statements of all in the course of their discussions, as exemplified below:

They don't look at how humans actually use the street; it's all about getting cars down that street because it's a major feeder route.

For bicyclists, as you come from Cedar toward El Camino Real, on each block the risk factor increases.

Coming down that hill, there is no traffic light for a while, so that as a driver you don't even feel that you're going that fast. But when I'm walking that stretch it feels really dangerous.

It's hard to go the speed limit on that (westerly) section because there don't seem to be a lot of things you have to worry about.

The intersection that is most likely to have senior citizens crossing is the most dangerous.

When you're driving along in your metal box you don't deal with people the same way you do when you're on the sidewalk. Passing someone as a pedestrian you are likely to recognize people, even say "hi".

When there is greenery on a street, it seems like you're part of nature; you're a little more connected to the earth.

You think about how much of a street goes toward cars versus pedestrians; when the sidewalk is really narrow as a pedestrian you kind of feel like 'we're not very important here'.

The focus groups echoed, to a large degree, the judgments pronounced in the answers to survey questions. Lombard Street and San Carlos Avenue were deemed in both focus group dialogs and survey responses to be uncomfortable, unsafe, and even unattractive. In comparison, King Street - The Embarcadero and Castro Street were judged, in the terminology proposed by Jones, et al. (2007), to be good places as well as good links. The middle cases in each street cohort, Participants saw The Alameda and California Avenue each as flawed but with great potential. Residents and business people expressed affection for as well as exasperation with these streets. The question for these streets was whether they would fulfill their potential or slide into shabbier versions of their present selves. Focus group participants implicitly and sometimes explicitly saw street re-design as an avenue to take for attainment of the more hopeful future.

The focus group results add value beyond that provided by the street user's and business surveys. The often-lively exchange of opinions, as well as the commentary of individuals based on their own personal experiences, added unique illumination to this research. There is also scientific value in repetition of results across methods of inquiry, which has largely been the case in this research into what makes streets active and sustainable.

Visual assessment.

Visual assessment results reflect a kind of composite visual judgment of the quality of a street. The look of a street may itself invite or deter its use. As described in Chapter 3, a group of respondents, both focus group members and others, assessed the visual quality of each of the six streets in the research. Each rater individually graded a set of photographs of street scenes in either the Big City or the Small City cohort, respectively. Grading was on the standard US academic scale: A (excellent), B (good), C (average), D (poor); and F (failure) The letter grades were translated into numerical equivalents, from 4 (for an A grade) to 0 (for an F grade). Participants appraised photos of their own street and the two companion streets in the same cohort. The purpose of this exercise was to supplement the opinions on street appearance given by participants in the street user's and business surveys as well as during the focus group sessions. Appendix A contains the complete set of pictures used for this assessment.

The visual assessment results produced a mixed verdict for test or study streets. While Castro Street out-performed both of its control streets, raters graded King Street - The Embarcadero even with one of its control streets, although far ahead of the other. Figures 59 and 60 reveal the visual assessment results.

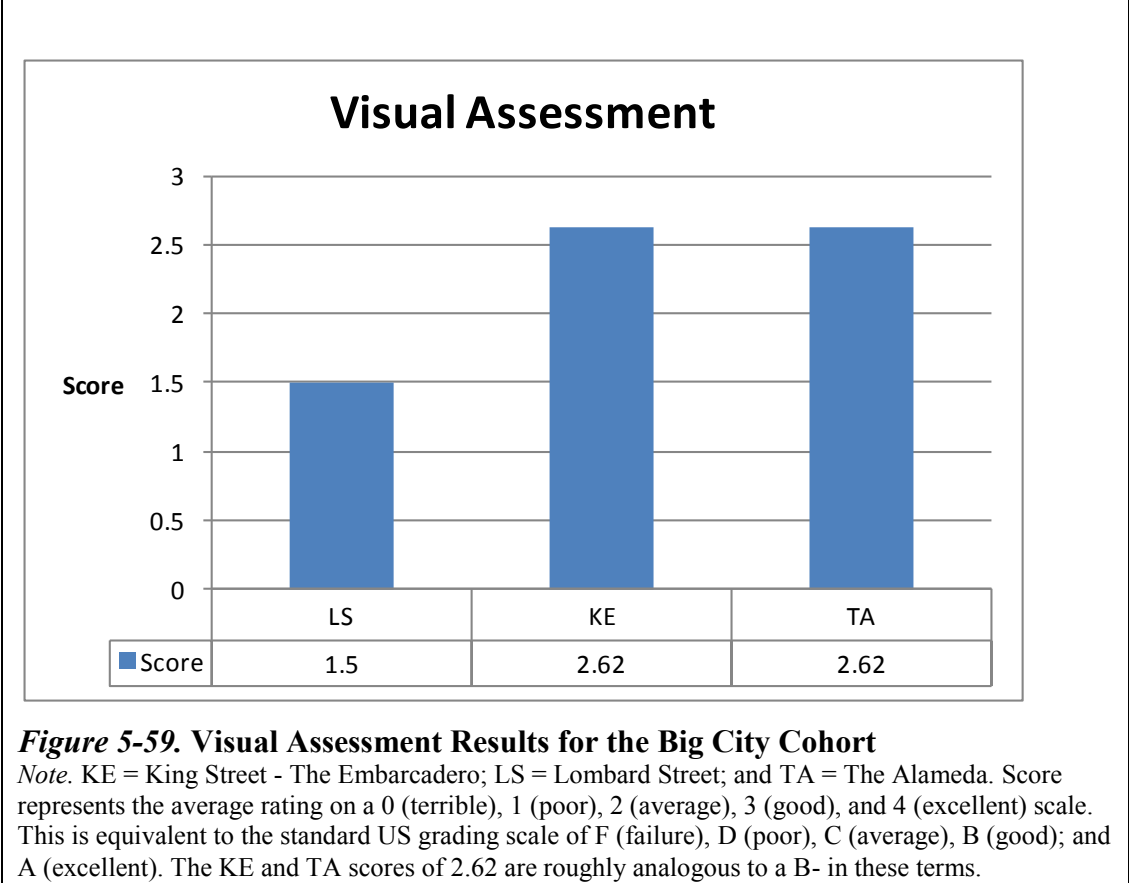


Table 19 details findings of a test for statistical significance of the difference in ranks for visual assessment between King Street - The Embarcadero and Lombard Street, the lowest rated of the Big City streets. I used the Mann-Whitney U test, a nonparametric equivalent of the Student’s t-test, to determine if there was a statistically significant difference between ranks of two groups (Gibbons, 1993b). The test results showed that King Street - The Embarcadero had a visual assessment score that was statistically significantly higher than the score given Lombard Street.

Table 5-19

Mann-Whitney U Test⁸⁸ for Comparison of Visual Assessment Score Ranks: King Street – The Embarcadero and Lombard Street

Variable/parameters
$\alpha = .05$, 1 –tailed test
$H_0 = p_a - p_b \leq 0$
$H_a = p_a - p_b > 0$
$U = 22,399.5$
$n_1 = n_2 = 164$
Mann-Whitney u test $p < .01$
Mann-Whitney u test $p < \alpha = .05$ therefore the distribution of ranks in the two groups differs significantly, thus H_0 is rejected.

Note. KE = King Street – The Embarcadero and LS = Lombard Street.

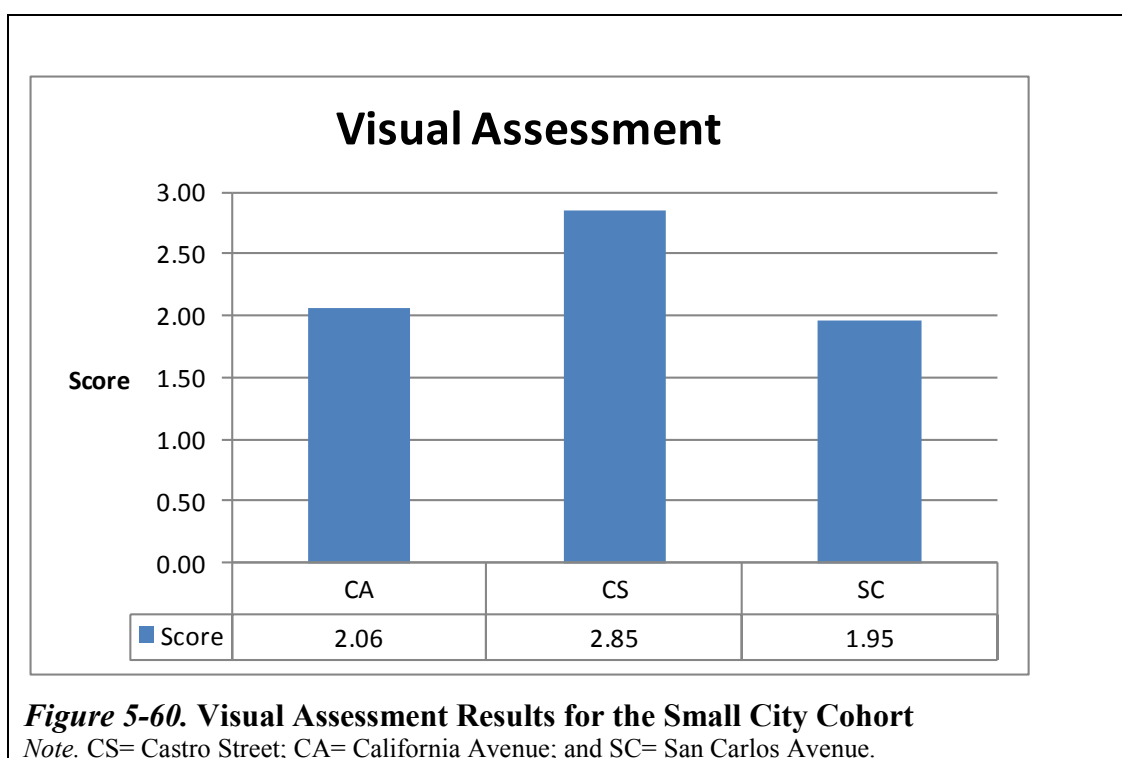


Table 20 summarizes statistical significance testing of the difference in visual assessment ranks between Castro Street and its nearest rival, California Avenue. Results showed that Castro Street score was statistically significantly greater than California Avenue's score at an $\alpha = .05$ level. The three Big City and three Small City

⁸⁸ The Mann Whitney U test (also called the Wilcoxon Rank Sum test) is the nonparametric equivalent of the Student's t test used on ordinal data to determine whether two distributions of rank-order data are significantly different from each other (Gibbons, 1993a). The test is set up so that the null hypothesis is that there is no difference.

assessment groups ranked streets in each cohort in broadly similar ranks, suggesting limited if any bias on the part of a given street user group in favor of its “own” street.

Table 5-20

Mann-Whitney U Test for Comparison of Visual Assessment Score Ranks: Castro Street and California Avenue

Variable/parameters
$\alpha = .05$, 1 –tailed test
$H_0 = p_a - p_b \leq 0$
$H_a = p_a - p_b > 0$
$U = 69,577.5$
$n_1 = n_2 = 308$
Mann-Whitney u test $p < .01$
Mann-Whitney u test $p < \alpha = .05$ therefore the distribution of ranks in the two groups differs significantly, thus H_0 is rejected.

Note. CS = Castro Street and CA = California Avenue.

These results agree with some and diverge from other findings from a seminal visual assessment study of main street characteristics in New Jersey (Ewing et al., 2005b). While King Street - The Embarcadero and The Alameda had high marks on visual assessment and the fewest (or tied for the fewest) number of travel lanes in their respective cohorts, both also had comparatively low amounts of buffer area for pedestrians. Raters gave The Alameda, the same high visual assessment score as King Street - The Embarcadero. While The Alameda had comparatively large amounts of tree canopy and pedestrian buffer, it also had the most vacant street frontage. San Carlos Avenue, which did poorly in visual assessment, had comparatively low levels of street front vacancy and tree canopy, but also substantial pedestrian buffer area. Similarly, while King Street - The Embarcadero and Castro Street each took away honors within their respective cohorts for the best results in the Street User’s Survey question on street attractiveness, The Alameda was a distant second among the three Big City street sections in the attractiveness survey question. At the same time, The Alameda was level with King Street - The Embarcadero in visual assessment score. Clearly different combinations of factors weight differently among residents to questions like attractiveness and in visual assessments to produce some complex results. The single unifying and clarifying theme in comparing visual assessment and street attractiveness results, however, is that the two test street sections did very well on both evaluations.

Visual assessment has the inherent limitation of the selection of scenes presented to raters. Both the quality and the representativeness of the visual images depend on a variety of factors. These include the photographer's ability and equipment, the nature of the light in scenes photographed, the specific locations on each street selected for viewing, weather conditions, and many other factors. Moreover, still and video images of street scenes cannot convey the sensory and social experience of actually using a street. The latter is what informs stakeholder surveys and focus group discussions, but not the one-dimensional views of a photograph. The next section explores in detail the statistical association between street use and the street attributes discussed in the preceding pages.

Data relationships: comparative street metrics, test and control streets.

Street attributes affect street performance, including activity and sustainability. The outcome variables for assessment of street activity and sustainability comprise a set of metrics for pedestrian, bicycle, and public transport use of streets. The influence variables of street environs are those characteristics presumed to impact street use. In this research, I distilled these variables into a set of metrics. Illuminating the relationship between outcome and influence was a core purpose of the inquiry.

Street activity metrics for test and control streets.

An important focus of this research has been in delineating the difference between different types of streets and accompanying activity levels, particularly those pertaining to walking, bicycling, and public transport use. As discussed in Chapter 3, as the design of this research is wide in scope of variables studied but narrow in sample size, statistical analysis can yield highly suggestive rather than definitive results. Nevertheless, the wide range of relationships examined provides a trove of research evidence.

The principal metrics used in this dissertation to define an active, sustainable street measure the amount of pedestrian, bicycle, and public transit patron activity on a street. These include pedestrians walking along or crossing a street, pedestrians sitting or standing, pedestrian interactions with one another, bicyclists along and turning into or from a street, and public transport boardings along a street. I compared the rankings of the two test or study street segments to the rankings of the four control street segments for each of these variables. Given the extremely small sample size used in the application of the Wilcoxon Rank Sum nonparametric

statistical test, none of the relationships tested were found to have p values less than .0667, just above the .05 level of statistical significance. Three variables had p values at .0667 level: Number of people walking along or across a street, number of people sitting or standing along a street, and pedestrian interactions. The number of daily public transport boardings had a p value of .1333. Table 21 summarizes these findings. The Wilcoxon Rank Sum test used in this analysis compares rankings of the two types of streets across six outcome variables. The Wilcoxon Rank Sum test is a preferred tool to analyze ordinal data in small samples (Gibbons, 1993b).

Figures 61 through 66 display a summary of the differences between test and control streets with respect to each outcome variable. Each Figure shows the mean value for each of the two test and four control street segments, along with the median value for the test⁸⁹ and control groups. In every case, the median value for amount of street activity was higher for the test streets compared to that for the control streets. The median for the test streets was more than double that of the control streets in total pedestrian volumes, more than quadruple in number of stationary pedestrians, two-thirds more for pedestrian crossing volumes, triple that for pedestrian interactions, three-and-a half times more for bicycle volumes, and ten times more for public transport boardings (although the latter result was skewed by the higher light rail capacity on King Street – The Embarcadero compared to the other streets). For three of the six outcome variables (total pedestrian volumes, pedestrians crossing, and pedestrian interactions), the mean values for each of the control streets was higher than that of any of the control streets.

⁸⁹ Since the test group had only two streets, the median and the mean values value for each of the variables for this group was the same.

Table 5-21

Wilcoxon Rank Sum Test Results for the Difference in Ranks of Measures of Street Activity in Study (or Test) Compared to Control Streets

Variable/ Test conditions	1-Sided Wilcoxon Exact p-value	Result
Pedestrians along and crossing street	.0667	H ₀ is rejected at $\alpha = .10$.
Pedestrians crossing street	.2667	H ₀ is not rejected
Stationary pedestrians along street	.0667	H ₀ is rejected at $\alpha = .10$
Pedestrian interactions along street	.0667	H ₀ is rejected at $\alpha = .10$
Bicycles on/to/from street	.2667	H ₀ is not rejected
Public transport boardings	.1333	H ₀ is not rejected

$$H_0 = p_a - p_b \leq 0$$

$$H_a = p_a - p_b > 0$$

$$P > .05, .10$$

$$\text{Fisher's } p = .0094$$

If Wilcoxon Exact $p < \alpha = .05$, H₀ is rejected at $\alpha = .05$

If Wilcoxon Exact $p > \alpha = .05$, H₀ is not rejected at $\alpha = .05$

If Wilcoxon Exact $p < \alpha = .10$, H₀ is rejected at $\alpha = .10$.

If Wilcoxon Exact $p > \alpha = .10$, H₀ is not rejected at $\alpha = .10$

If rejected, the distribution of ranks differs significantly

If not rejected, the distribution of rank does not differ significantly

Comparing Test and Control Street : Pedestrians Along and Across

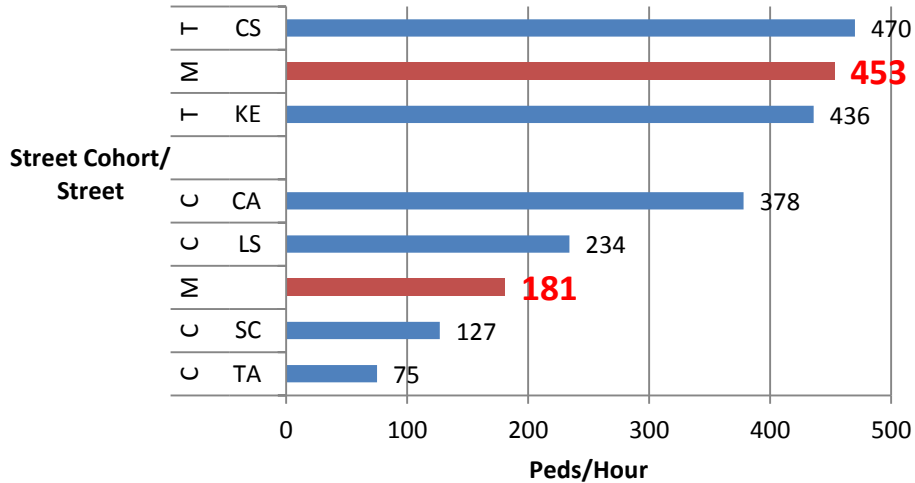


Figure 5-61. Comparison of Test and Control Streets: Total Pedestrian Volumes

Note. C = Control street; T = Test street; M = median value; KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Peds = pedestrians.

Comparing Test and Control Streets: Pedestrians Crossing

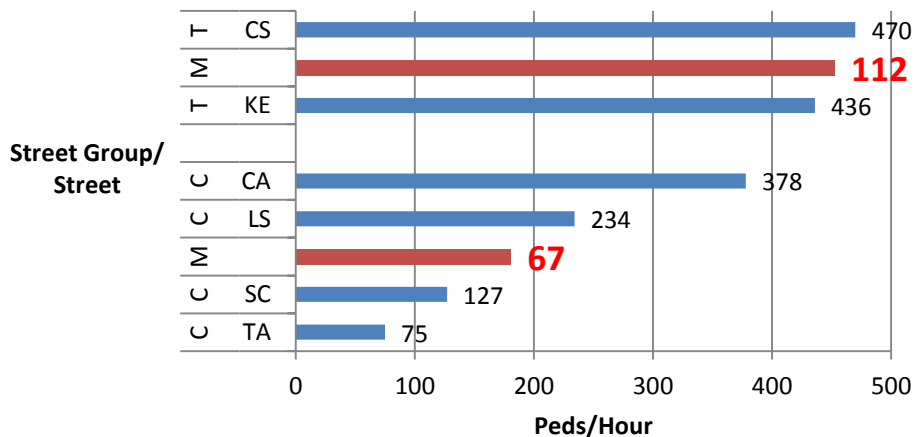


Figure 5-62. Comparison of Test and Control Streets: Pedestrians Crossing Street

Note. C = Control street; T = Test street; M = median value; KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; C S= Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Peds = pedestrians.

Comparing Test and Control Streets: Standing or Sitting Pedestrians

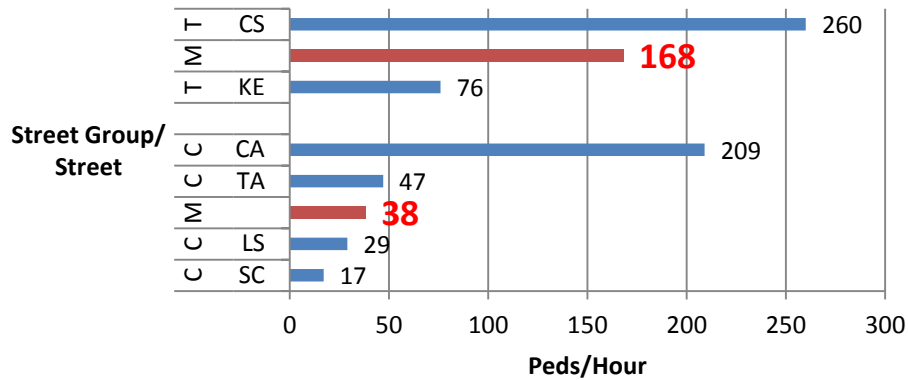


Figure 5-63. Comparison of Test and Control Streets: Stationary Pedestrians

Note. C = Control street; T = Test street; M = median value; KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; C S = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Peds = pedestrians.

Test and Control Streets Comparison: Pedestrian Interactions

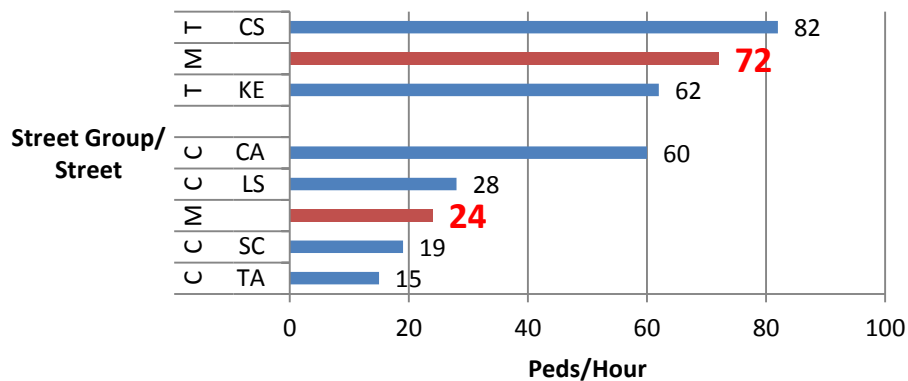


Figure 5-64. Comparison of Test and Control Streets: Pedestrian Interactions

Note. C = Control street; T = Test street; M = median value; KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; C S = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and Peds = pedestrians.

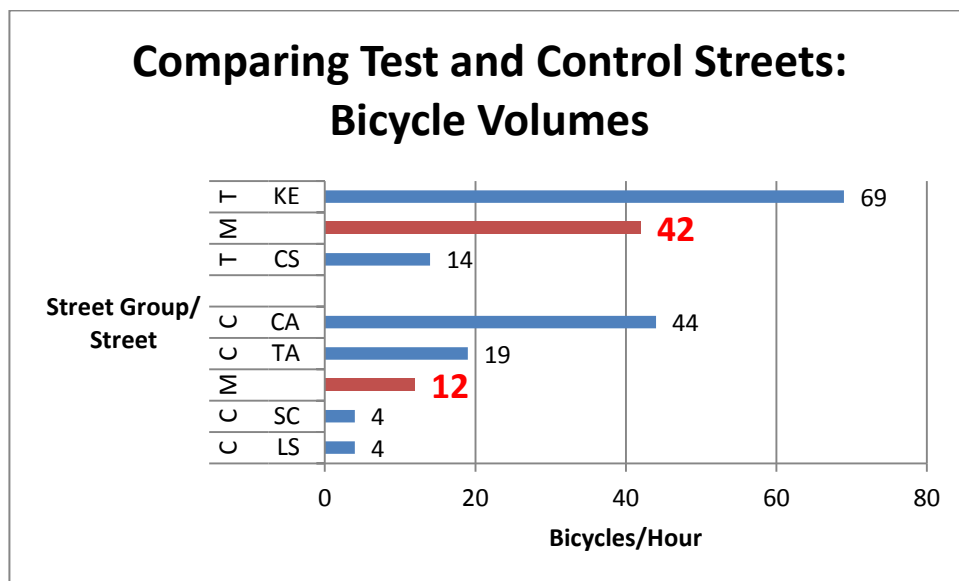


Figure 5-65. Comparison of Test and Control Streets: Bicycles To/From/Along Street

Note. C = Control street; T = Test street; M = median value; KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; C S = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

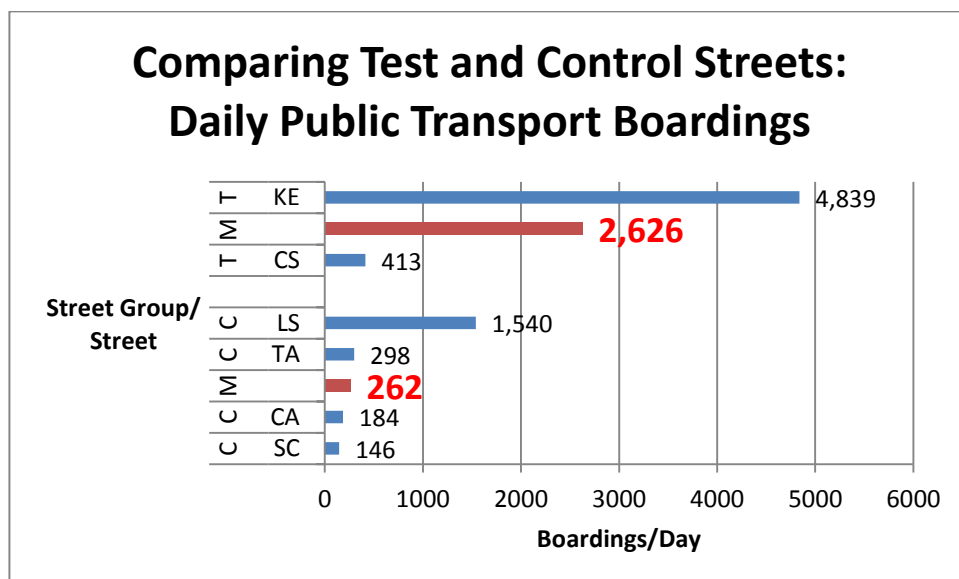


Figure 5-66. Comparison of Test and Control Streets: Public Transport Boardings Along Street

Note. C = Control street; T = Test street; M = median value; KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; C S = Castro Street; CA = California Avenue; and SC = San Carlos Avenue.

The two test streets proved more active as pedestrian venues than were the four control streets. Accordingly, King Street - The Embarcadero and Castro Street rate well in sheer pedestrian presence, what Marshall et al. (2004) deem to be an important indicator of socio-economic life. In the number of stationary pedestrians and interactions among pedestrians standing, sitting, or moving, these two exemplary streets also fare well on the Liveliness Index proposed by Mehta (2006). Since resource limitations precluded my collection of duration of stay data for the six streets in this dissertation research, however, this latter judgment must be partial only.

Similarly, the number of pedestrian interactions in relation to total number of pedestrians on the two test streets compared to the four control streets lead to a higher Social Performance Ratio, as proposed by Lillebye (2007). Since Wilcoxon Rank Sum test statistics for differences in rank order between the test and control streets in number of stationary pedestrians, total number of pedestrians, and pedestrian interactions, each at .0667, were just above the customary .05 probability level, these conclusions based on statistical analyses alone must be considered provisional. Notwithstanding this strictly statistical lack of significance at the level of $\alpha=.05$, which is largely an artifact of small sample size, the two exemplary streets had median values in pedestrian activity that were from double to triple that of the control streets. In all pedestrian-related variables, the control streets were in the ranks of either the top two or three of the six streets ranked.

There are no such clear distinctions between the test and control streets on bicycle use or public transport boardings. Rather than being grouped together near the top of the range as they were with pedestrian activity, there is a wide gap between the King Street - The Embarcadero and Castro Street in cycling and transit use. The superior travel time and comfort of continuous bicycle lanes in each direction and additional sidewalk width on the Bayside along King Street - The Embarcadero, along with the proximity of bicycle-friendly Caltrain service, are likely explanations of that street's position at the top rung of the ladder in bicycle use. This result would accord with research by both Rietveld and Daniel (2004) and Hunt and Abraham (2007) on the high value assigned by cyclists to such infrastructure. Analogously, better public transit infrastructure is likely to give King Street - The Embarcadero an advantage in transit use. This street has the only continuous, dedicated public transport right-of-way of the six street sections and has higher capacity transit than

any of the other streets. Nevertheless, the median value for bicycle use on the two test streets is three times that for control streets and transit use shows the same scale of difference.

There are many other potential influences on street use. Determining what these influences are and how important they may be has been an important task in this research.

Findings for Street Attributes

The preceding section compared characteristics of streets and street cohorts. This section investigates the relationship between the attributes of streets and street environs metrics of street activity and sustainability.

Association between influence and outcome variables.

This research emphasizes investigation of the relationships among an extensive set of presumed influence variables to outcome variables pertaining to the presence and activity of pedestrians, bicyclists, and public transport patrons. Once again, the constraints of a small street sample size in the research design preclude definitive or explanatory statistical results. Nevertheless, a non-parametric statistical exploration of associations produces many suggestive results, especially when put in the broader context of other research findings discussed in previous sections of this chapter and in the research literature explored in Chapter 2. The pages to follow highlight ranks of variables with the strongest positive or negative associations.⁹⁰

Associations with pedestrian activity and presence.

I ranked the six street sections in order of the volume of people walking along and number of people crossing each street, as well as the number of interactions recorded between and among these pedestrians. The resulting rank order of the total number of pedestrians walking along and crossing the street was the same as that for total number of pedestrian interactions along the street for the set of six streets in this research. As a result, the rank order associations with these two outcome variables were also the same.

The highest degree of association for each was with linear feet of restaurant frontage and proportion of street right-of-way dedicated to pedestrian use. There were also weaker positive associations with an index of variables pertaining to

⁹⁰ A complete set of ranking correlations is available at the URDMS Curtin University research data repository.

design⁹¹ of a street and its environs and with both employment and the sum of population and employment within the environs of a street. While the restaurant frontage variable was the only one attaining a p value of less than .05, the small sample size of street sections in this dissertation research makes it more difficult to reach this standard than it would be for a larger sample size. Table 22 and Figures 67 through 71 summarize these results.

Notably, there was little association between street ranks by household median income and ranks by either total pedestrian volumes or pedestrian interactions. The same was true for street ranks of both bicyclists and public transport boardings.⁹² Chapter 7 explores the reasons for these results.

The finding that restaurants are important for pedestrian activity (while intuitively satisfying) confirms the view held by Untermann and Lewicki (1984) in their generative work on accommodating pedestrians. This result also supports the research by Moudon et al. (2006) and by Mehta (2006), who found that pedestrian activity was often associated with proximity of places to eat and/or drink. The importance of sidewalks and side paths to pedestrians is well supported and documented in research by Landis et al. (2001), Giles-Corti and Duncan (2003), Shay et al. (2003), Owen et al. (2004), Moudon et al. (2006), and Forsyth et al. (2008).

⁹¹ The Design index is comprised street ranks by proportion of street right of way dedicated to motor vehicle traffic and street ranks by number of motor vehicle travel lanes, pedestrian lateral connections, commercial driveways, and signalized crossings.

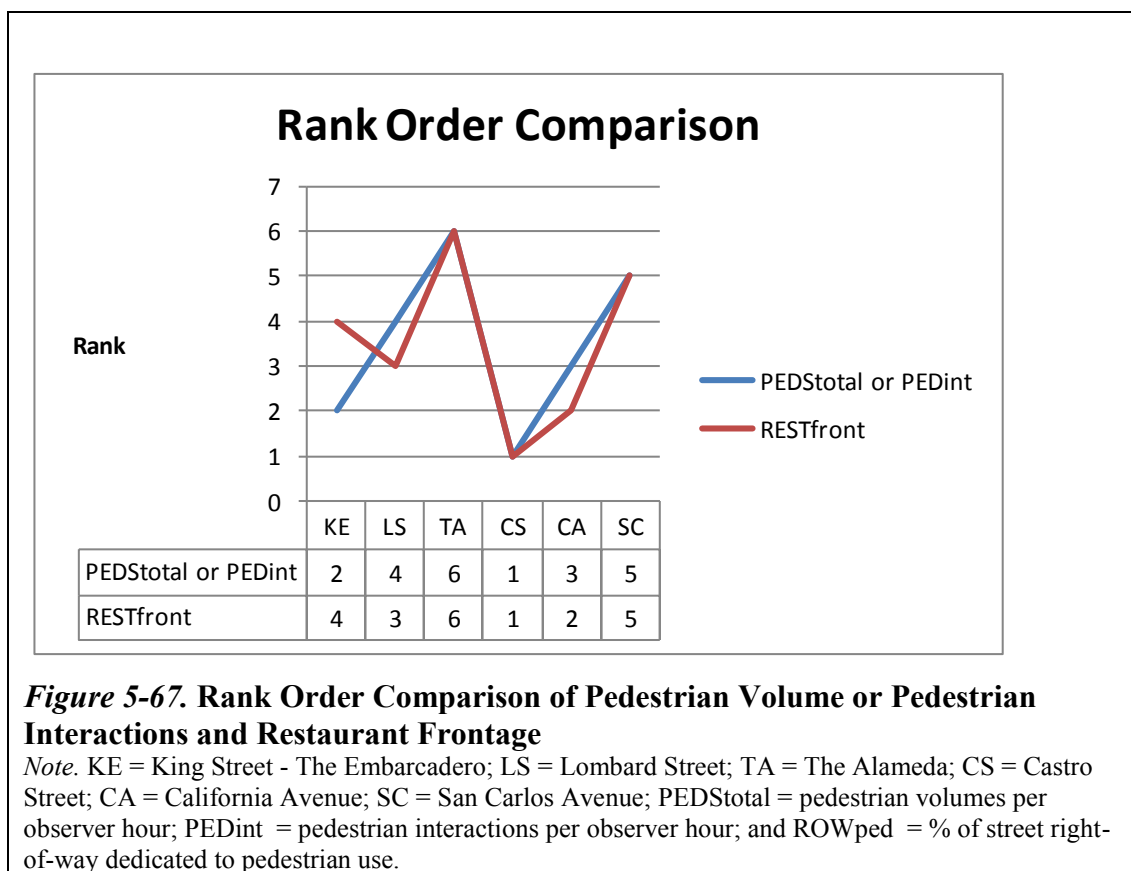
⁹² These results are available in the URDMS Curtin University research data repository.

Table 5-22

Spearman's Rank Order Test Results for Strength of Association Between Ranks of Pedestrian Volume/Interactions and Ranks of Street Context Metrics: Strongest Associations

Ped Volume or ped interactions/ Test conditions	Compared to: (street context variable)	RS statistic =	2-tailed test p =
N = 6, DF = 4 2-tailed test			
	RESTfront	.83	.0416
	ROWped	.77	.0724
	DESIGN	.71	.1108
	EMP	.60	.2080
	POPEMP	.54	.2657

Note. PEDStotal = pedestrian volumes per observer hour; PEDint = pedestrian interactions per observer hour; RESTfront = restaurant frontage, linear feet per mile or km; ROWped = % of street right-of-way dedicated to pedestrian use; DESIGN = an index of ranks of street and environs design variables; EMP = employment within .25 mile or .4km of street centerline; and POPEMP = population and employment within .25 mile or .4km of street centerline. Only associations with RS statistics about .50 are shown.



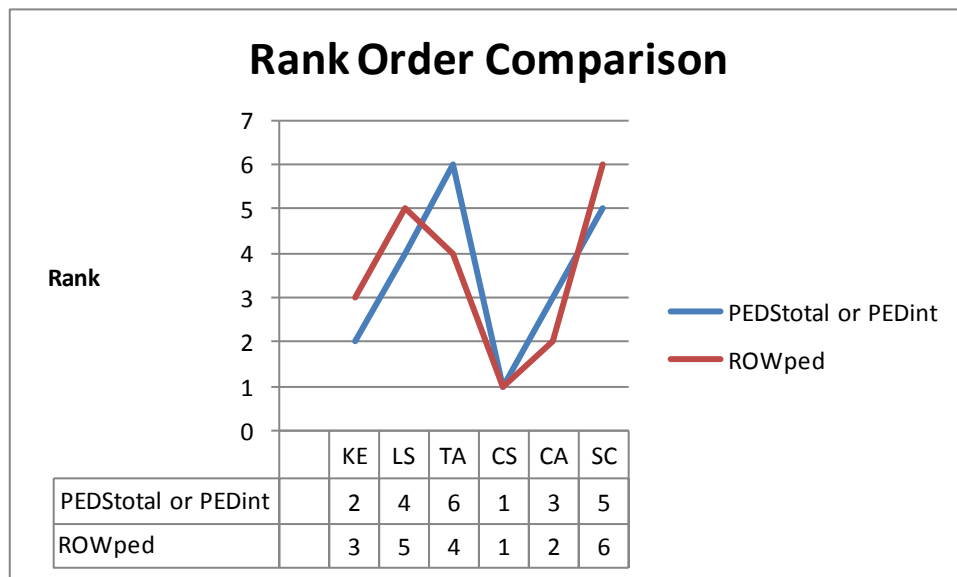


Figure 5-68. Rank Order Comparison of Pedestrian Volume or Pedestrian Interactions and Right-of-Way (ROW) for Pedestrians

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDStotal = pedestrian volumes per observer hour; PEDint = pedestrian interactions per observer hour; and ROWped = % of street right-of-way dedicated to pedestrian use.

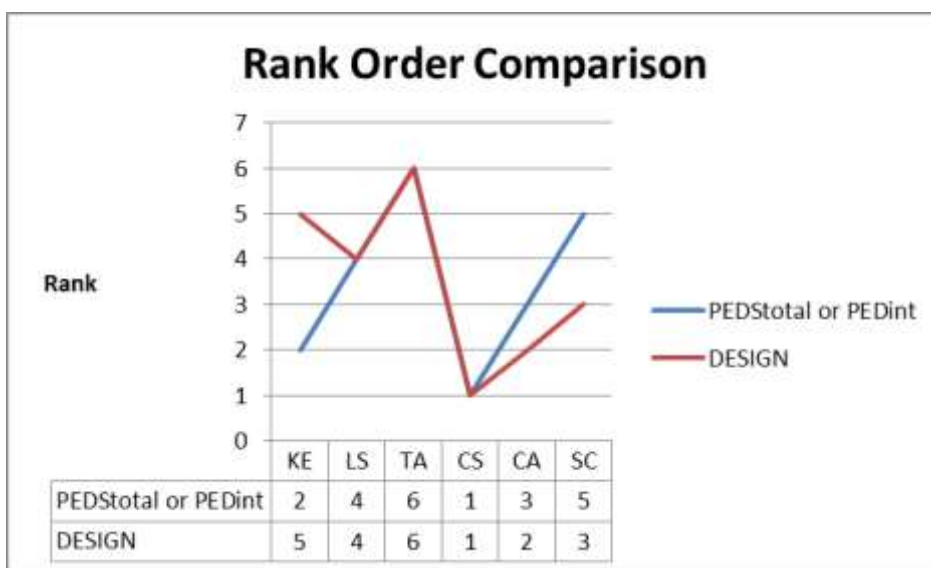


Figure 5-69. Rank Order Comparison of Pedestrian Volume or Pedestrian Interactions and Design Index

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDStotal = pedestrian volumes per observer hour; PEDint = pedestrian interactions per observer hour; and DESIGN = an index of ranks of street and environs design variables.

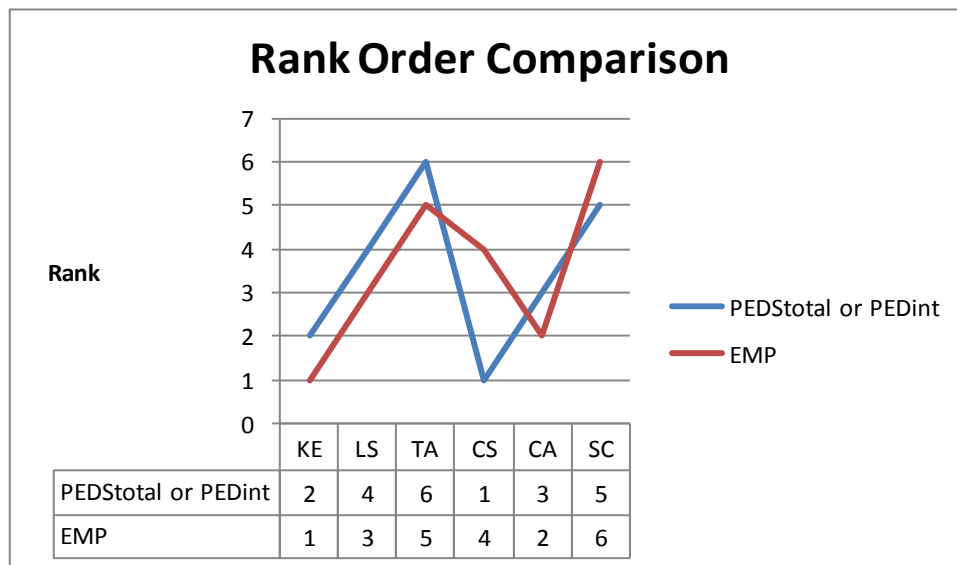


Figure 5-70. Rank Order Comparison of Pedestrian Volume or Pedestrian Interactions and Employment

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDStotal = pedestrian volumes per observer hour; PEDint = pedestrian interactions per observer hour; and EMP = employment within .25 mile or .4km of street centerline.

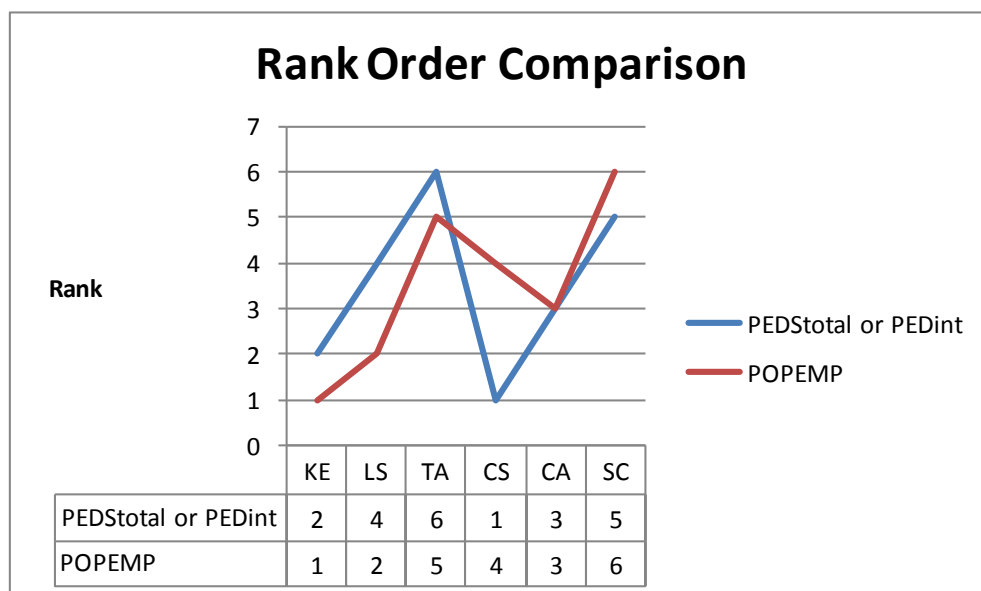


Figure 5-71. Rank Order Comparison of Pedestrian Volume or Pedestrian Interactions and Total Employment and Population

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDStotal = pedestrian volumes per observer hour; PEDint = pedestrian interactions per observer hour; and POPEMP = population and employment within .25 mile or .4km of street centerline.

Day et al. (2006) posit that perceptions about traffic and personal safety are important assessment measures of a walking environment. How are pedestrian safety and comfort, as indicated by both objective and subjective measures, associated with pedestrian activity? Neither the rank order of Pedestrian Safety Index nor that for the adjusted pedestrian crash rates described earlier in this chapter showed much association with ranks of total number of pedestrians or number of pedestrian interactions. There was such an association between perceived safety and perceived comfort, however, although neither reached customary significance threshold of $p = .05$. Nevertheless, perceived safety comes relatively close at $p = .07$ and perhaps a slightly larger sample size may have resulted in attainment of the standard statistical significance threshold. Table 23, Figures 72, and Figure 73 show these associations. Implicit in these findings is that a pedestrian's subjective perception of his or her environment may be a more important influence than the objective data on safety. In a strictly statistical sense, this finding is an original contribution as there is little in the literature on the disconnection between pedestrians' subjective assessment and objective measurements of the street environment.

Table 5-23

Spearman's Rank Order Test Results for Strength of Association Between Ranks of Pedestrian Volume/Interactions and Ranks of Perceived Street Safety and Comfort Metrics

Ped Volume or ped interactions/ Test conditions	Compared to: (street safety, comfort variable)	RS statistic =	2-tailed test p =
N = 6, DF = 4			
2-tailed test			
	PersSAFETY	.77	.0724
	PerCOMFORT	.71	.1108

Note. PED Volume = pedestrian volumes per observer hour; Ped interactions = pedestrian interactions per observer hour; PerSAFETY = proportion of "Very Safe" survey responses; and PerCOMF = proportion of "Very Comfortable" survey responses.

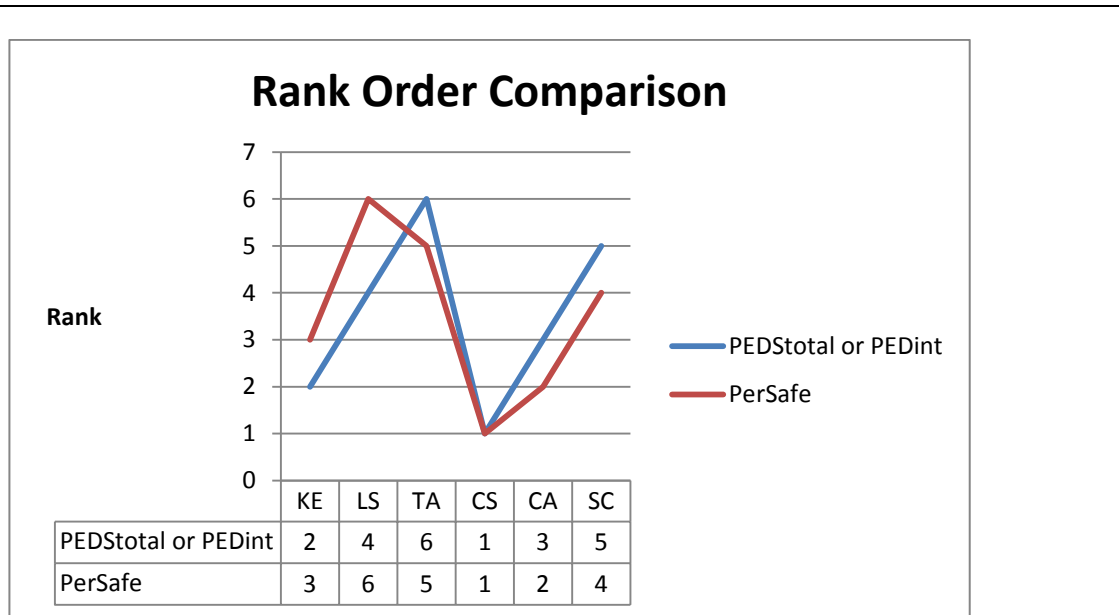


Figure 5-72. Rank Order Comparison of Total Pedestrians or Pedestrian Interactions and Perceived Safety

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDStotal = pedestrian volumes per observer hour; PEDint = pedestrian interactions per observer hour; and PerSafe = proportion of “Very Safe” survey responses.

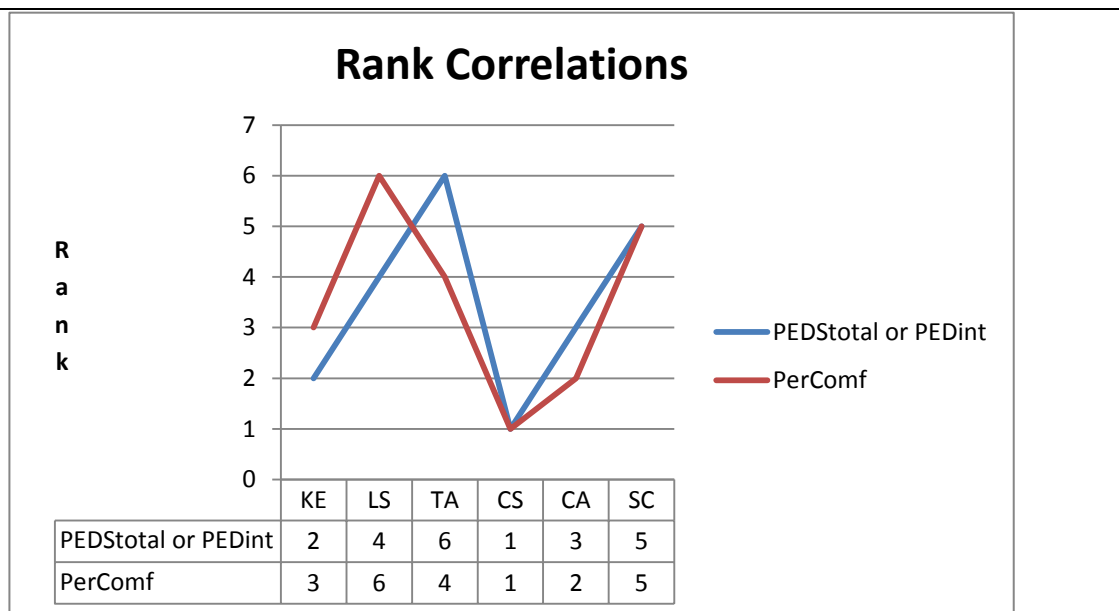


Figure 5-73. Rank Order Comparison of Total Pedestrians or Pedestrian Interactions and Perceived Comfort

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDStotal = pedestrian volumes per observer hour; PEDint = pedestrian interactions per observer hour; and PerComf = proportion of “Very Comfortable” survey responses.

Comparative rankings for number of stationary pedestrians (people sitting or standing) by street perfectly mirrored the rankings by street for proportion of street right-of-way dedicated to pedestrians. Rankings of stationary pedestrians were also positively associated with rankings of streets by street frontage in restaurant use, street frontage in retail use, and an index of design variables. There was a negative association with ranking by annual average daily motor vehicle traffic. Only the association with proportion of right-of-way dedicated to pedestrians, however, was significant at the $p = .05$ level. Table 24 summarizes these findings and Figures 74 through 78 depict these associations in graphical form for each variable.

Table 5-24

Spearman's Rank Order Test Results for Strength of Association Between Ranks of Stationary Pedestrians and Ranks of Street Context Metrics: Strongest Associations

Stationary Pedestrians/ Test conditions	Compared to: (street context variable)	RS statistic =	2-tailed test p =
N =6, DF = 4			
2-tailed test			
	ROWped	1.00	.0000
	RESTfront	.71	.1108
	RETfront	.54	.2657
	DESIGN	.54	.2657
	AADT	-.54	.2657

Note. PEDSsta = Pedestrians sitting or standing per observer hour; ROWped = %of street right-of-way dedicated to pedestrian use; RESTfront = restaurant frontage, linear feet per mile or km; RETfront = retail frontage, linear feet per mile or km; DESIGN = an index of ranks of street and environs; and AADT = annual average daily traffic volume. Only associations with RS statistics about .50 are shown.

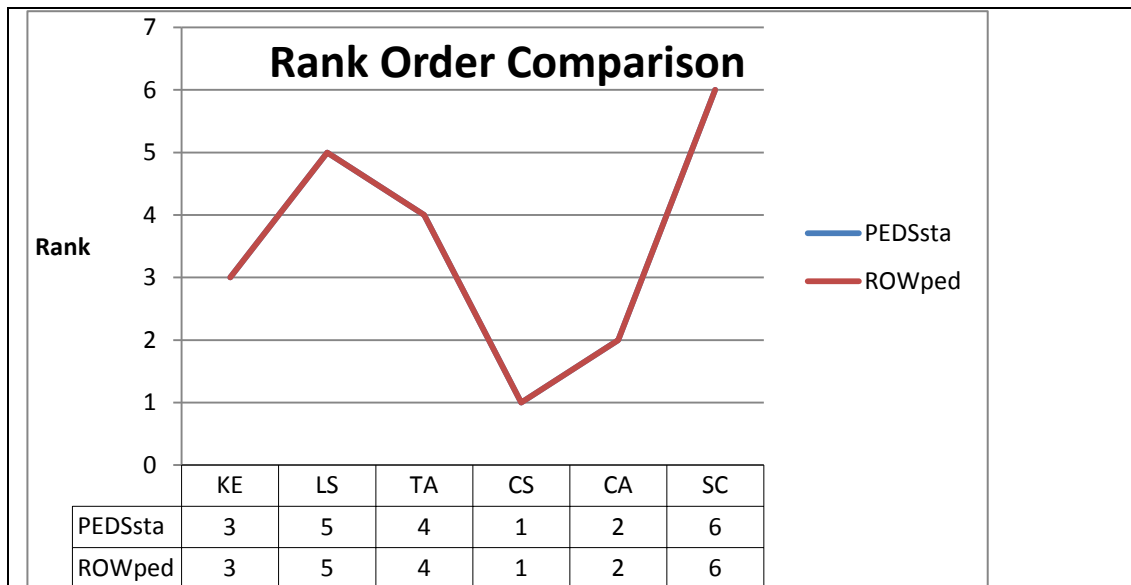


Figure 5-74. Rank Order Comparison of Stationary Pedestrians and Right-of-Way (ROW) for Pedestrians

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDSsta = pedestrians sitting or standing per observer hour; and ROWped = % of street right-of-way dedicated to pedestrian use.

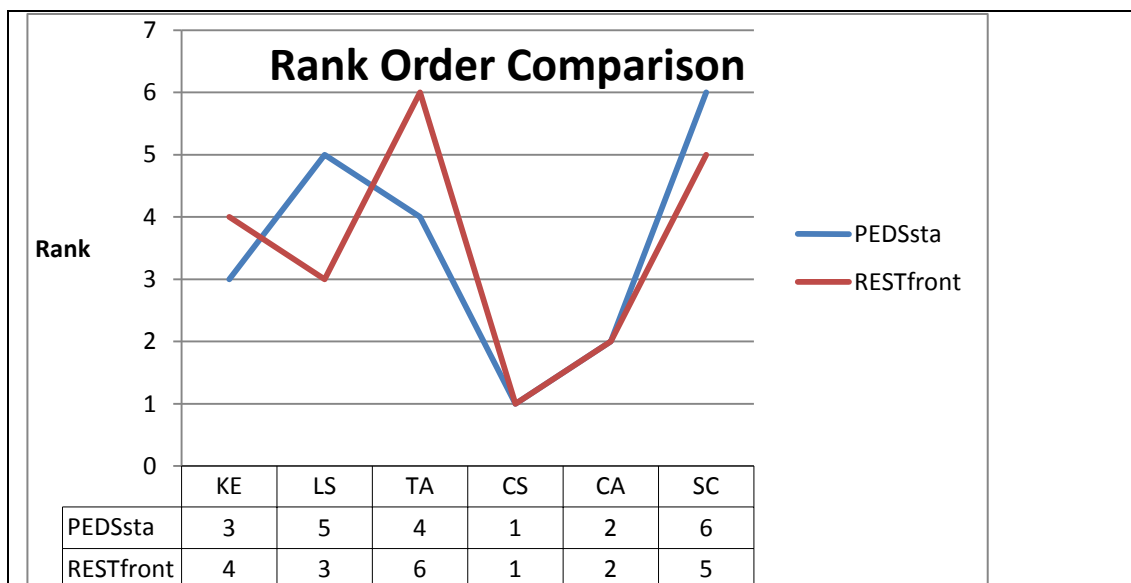


Figure 5-75. Rank Order Comparison of Stationary Pedestrians and Restaurant Frontage

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDSsta = pedestrians sitting or standing per observer hour; and RESTfront = restaurant frontage in linear feet per mile or km.

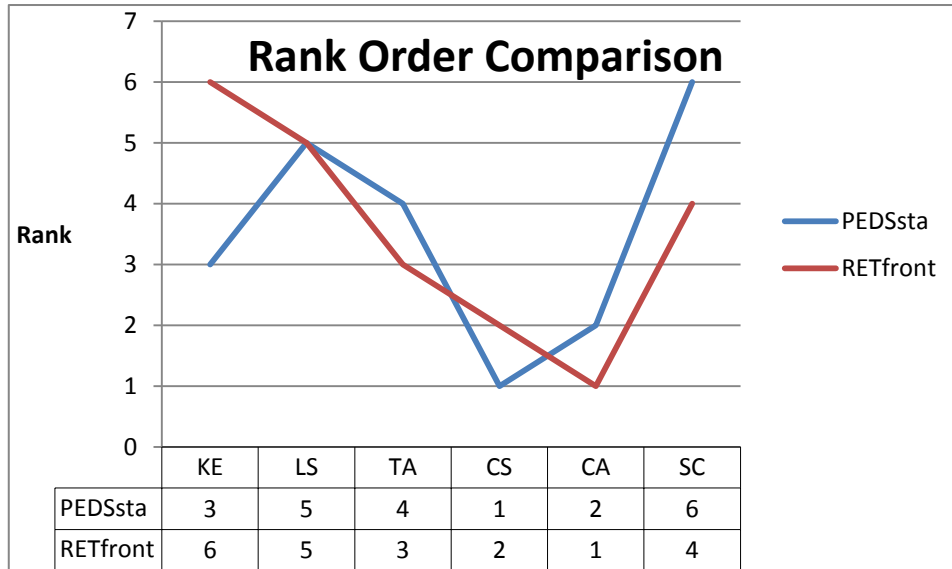


Figure 5-76. Rank Order Comparison of Stationary Pedestrians and Retail Frontage

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDSsta = pedestrians sitting or standing per observer hour; and RETfront = retail frontage in linear feet per mile or km.

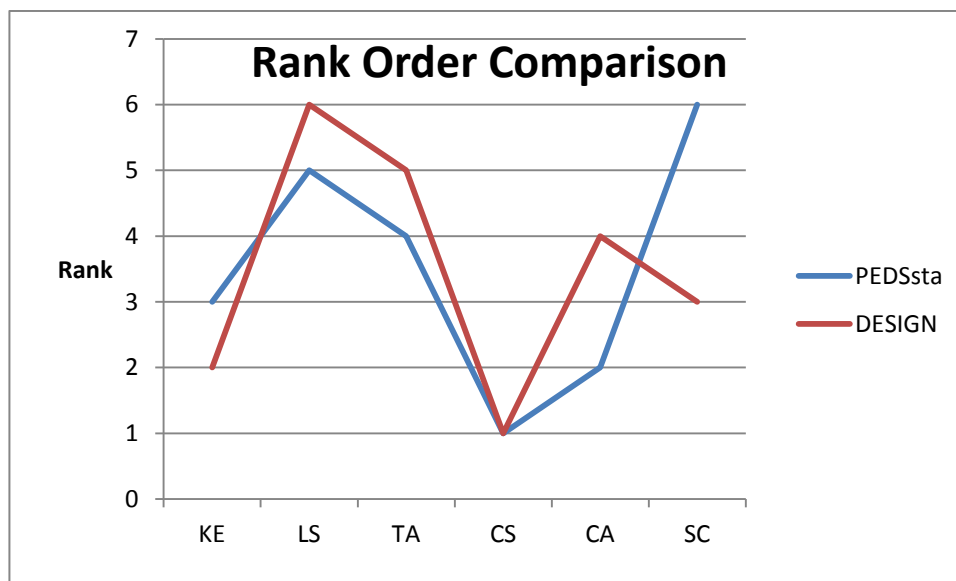
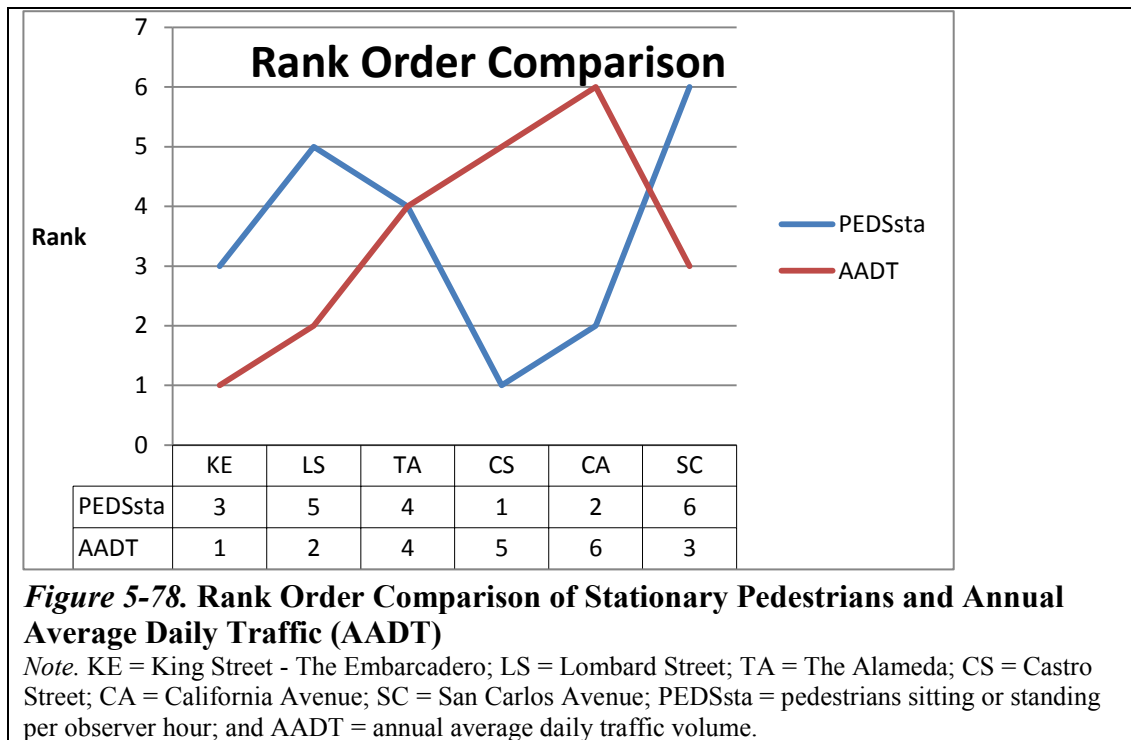


Figure 5-77. Rank Order Comparison of Stationary Pedestrians and Design Index

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDSsta = pedestrians sitting or standing per observer hour; and DESIGN = an index of ranks of street and environs design variables.



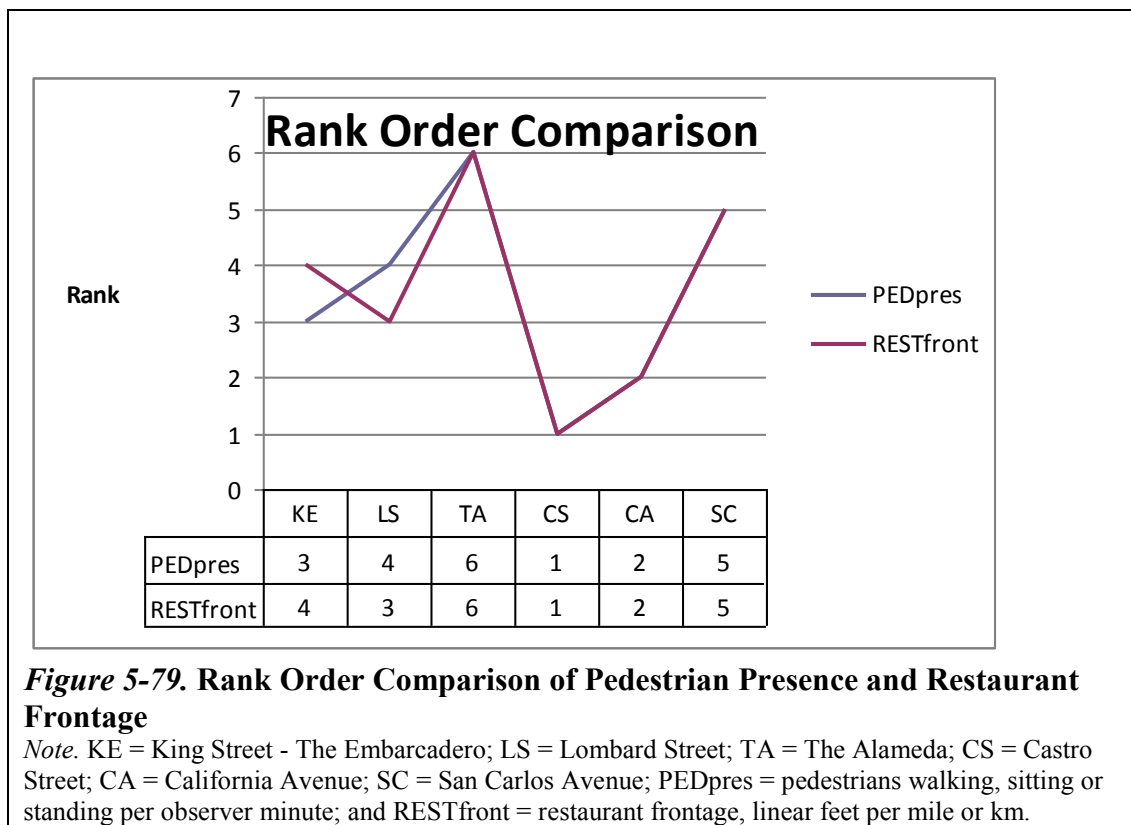
The rank order by street of overall pedestrian presence (both moving and stationary pedestrians) was most strongly associated with the ranking by street in amount of restaurant frontage and the proportion of right-of-way dedicated to pedestrians, both statistically significant at the $p = .05$ level. Other notable (but not statistically significant the .05 level) positive rank order associations were with an index of design variables, the sum of restaurant and retail frontage, street environs employment, and intersection density. A clearly negative rank order association was apparent with motor vehicle speeds. Table 25 and Figures 79 through 85 present these findings.

Table 5-25

Spearman's Rank Order Test Results for Strength of Association Between Ranks of Pedestrian Presence and Ranks of Street Context Metrics: Strongest Associations

Pedestrian presence/ Test conditions	Compared to: (street context variable)	RS statistic =	2-tailed test p =
N = 6, DF = 4 2-tailed test			
	RESTfront	.94	.0048
	ROWped	.83	.0416
	DESIGN	.71	.1108
	RSRTfront	.60	.2080
	EMP	.54	.2657
	Idensity	.54	.2657
	MVsports	-.71	.1108

Note. RESTfront = restaurant frontage, linear feet per mile or km; ROWped = % of street right-of-way dedicated to pedestrian use; DESIGN = an index of ranks of street and environs design; RSRTfront = retail or restaurant frontage, linear feet per mile or km; EMP = employment within .25 mile or .4km of street centerline; Idensity = # of intersections within and from either end .25 mile or .4km of street centerline; and MVsports = 85th percentile mid-section motor vehicle speeds. Pedestrian presence is the sum of pedestrians walking along or across a street and the number of pedestrians sitting or standing along a street. Only associations with RS statistics about .50 are shown.



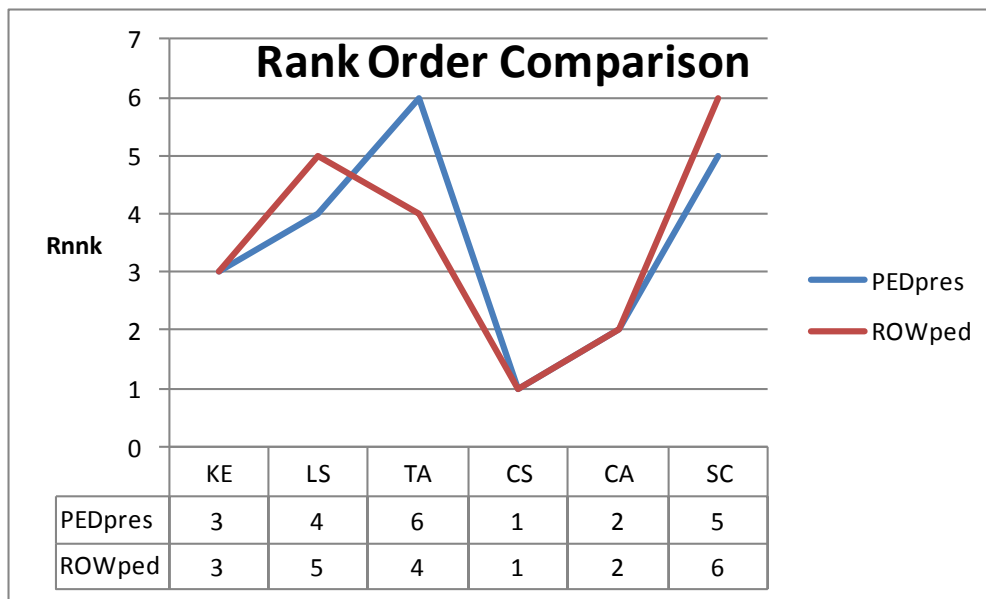


Figure 5-80. Rank Order Comparison of Pedestrian Presence and Right-of-Way (ROW) for Pedestrians

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDpres = pedestrians walking, sitting or standing per observer minute; and ROWped = % of street right-of-way dedicated to pedestrian use.

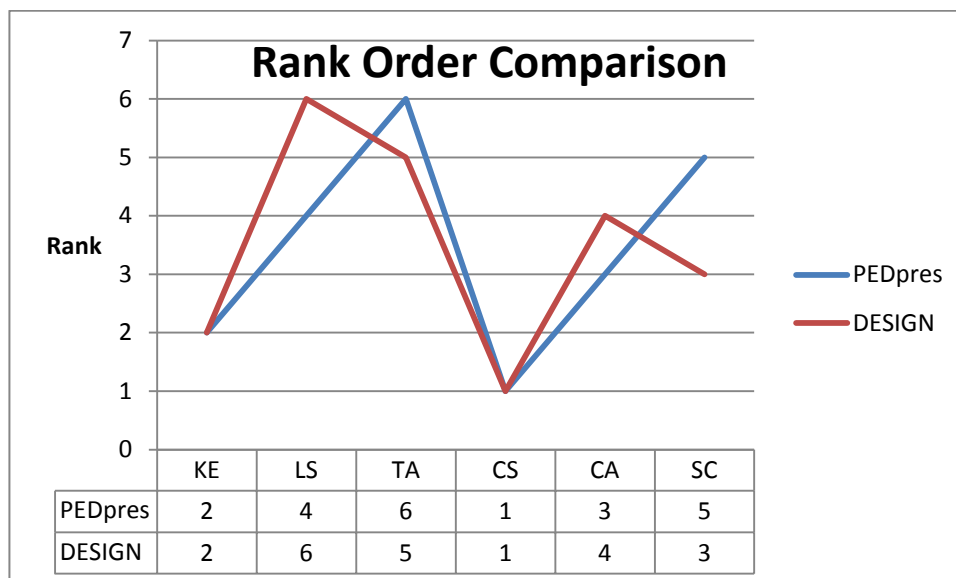


Figure 5-81. Rank Order Comparison of Pedestrian Presence and Design

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDpres = pedestrians walking, sitting or standing per observer minute; and DESIGN = an index of ranks of street and environs design.

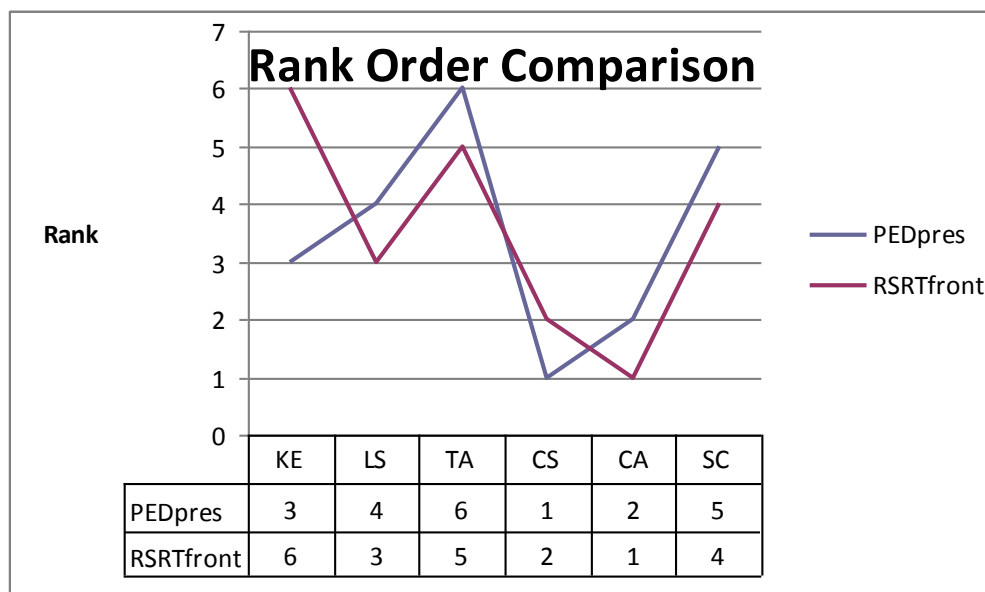


Figure 5-82. Rank Order Comparison of Pedestrian Presence and Retail & Restaurant Frontage

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDpres = pedestrians walking, sitting or standing per observer minute; and RSRTfront = sum of restaurant and retail frontage, linear feet per mile or km.

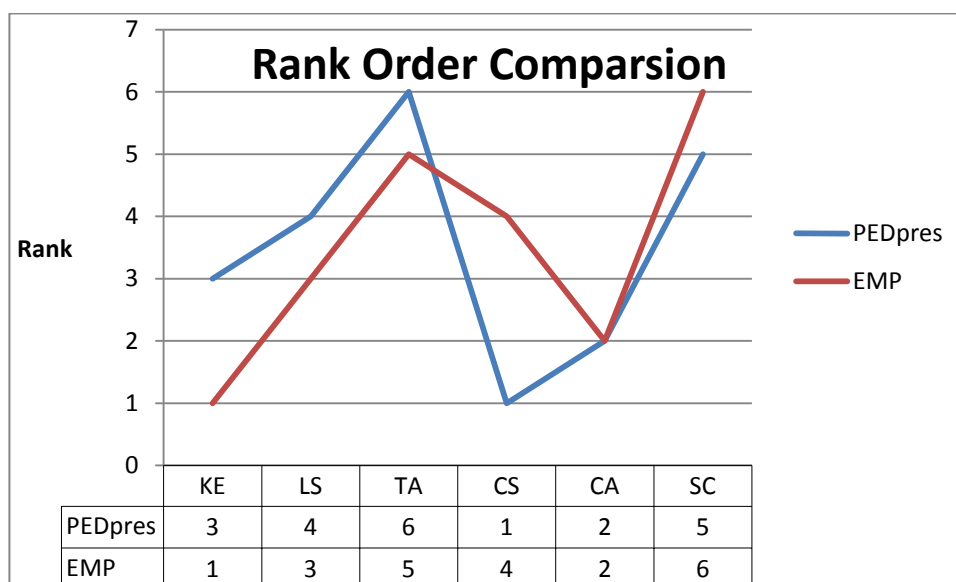


Figure 5-83. Rank Order Comparison of Pedestrian Presence and Employment

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; and EMP = employment within .25 mile or .4km of street centerline.

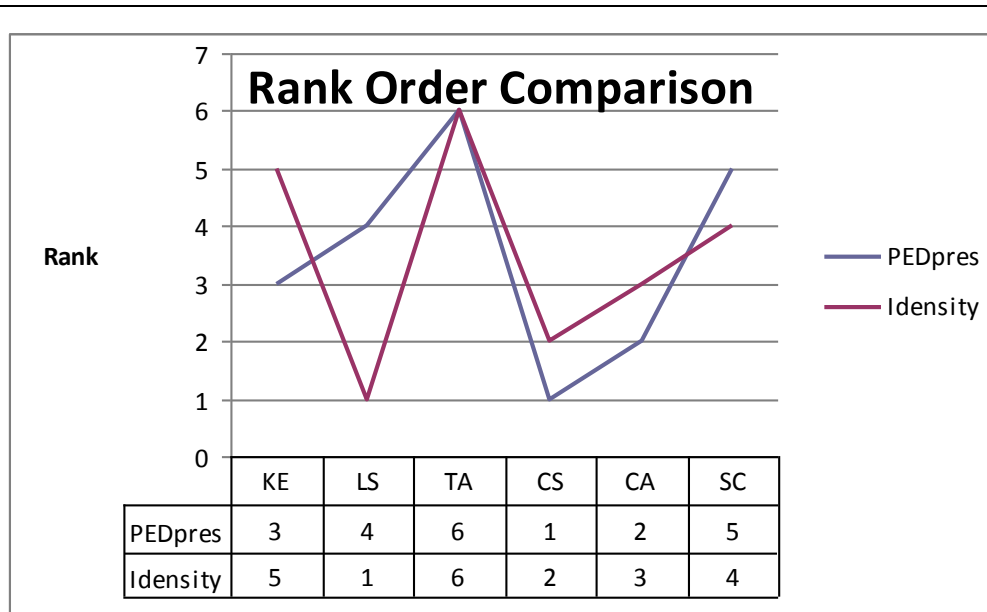


Figure 5-84. Rank Order Comparison of Pedestrian Presence and Intersection Density

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDpres = pedestrians walking, sitting or standing per observer minute; and Idensity = # of intersections within and from either end .25 mile or .4km of street centerline.

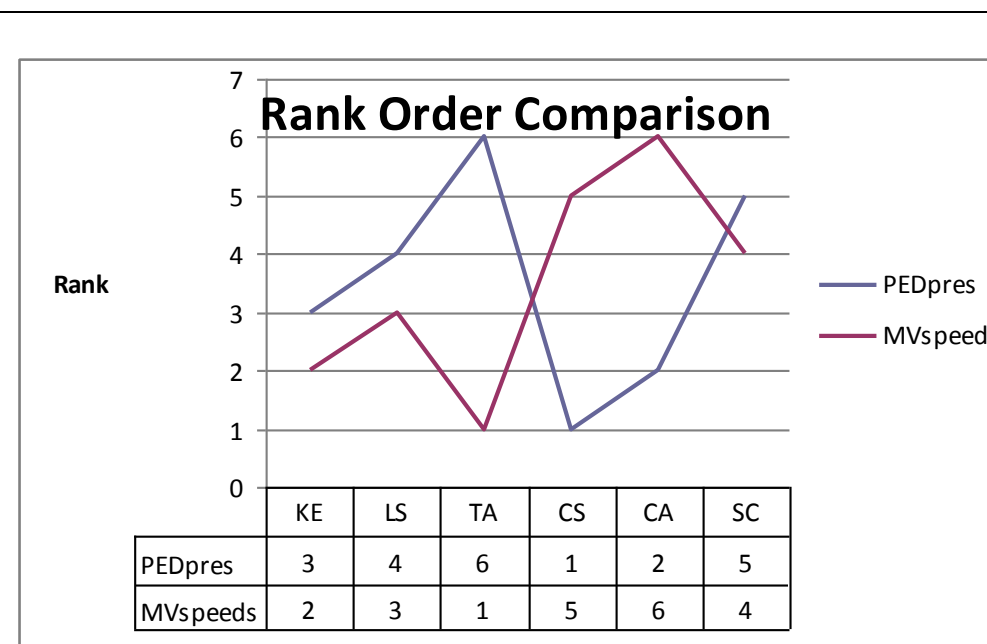


Figure 5-85. Rank Order Comparison of Pedestrian Presence and Motor Vehicle Speeds

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PEDpres = pedestrians walking, sitting or standing per observer minute; and MVspeeds = 85th percentile mid-section motor vehicle speeds.

Associations with bicyclist activity and presence.

The rank order by street of right-of-way dedicated to pedestrians and/or bicyclists had the strongest association with rank order of number of bicyclists using a street, although this relationship did not reach the $p = .05$ level of significance. There were also notably positive associations of total employment in the street environs and intersection density with ranks of streets by bicycle use. Table 26 and Figures 86 through 88 reveal these results. The findings on the importance of space for cycling to the demand for cycling confirm earlier research by Nelson & Allen (1997), Harkey et al. (1998), Dill and Voros (2007), Hunt and Abraham (2005), Titze, Stronegger, Janschitz, and Oja (2008), and Krizek (2006).

Table 5-26

Spearman's Rank Order Test Results for Strength of Association Between Ranks of Bicycles To/From/On and Ranks of Street Context Metrics: Strongest Associations

Pedestrian presence/ Test conditions	Compared to: (street context variable)	RS statistic=	2-tailed test p=
N=6, DF =4 2-tailed test			
	ROWnm	.77	.0724
	EMP	.60	.2080
	Idensity	-.60	.2080

Note. BIKEStra = Bicycles to, from, along street per observer minute; ROWnm = % of street right-of-way dedicated to bicycle and pedestrian use; EMP = employment within .25 mile or .4km of street centerline; and Idensity = # of intersections .25 mile or .4km within and from either end of street centerline.

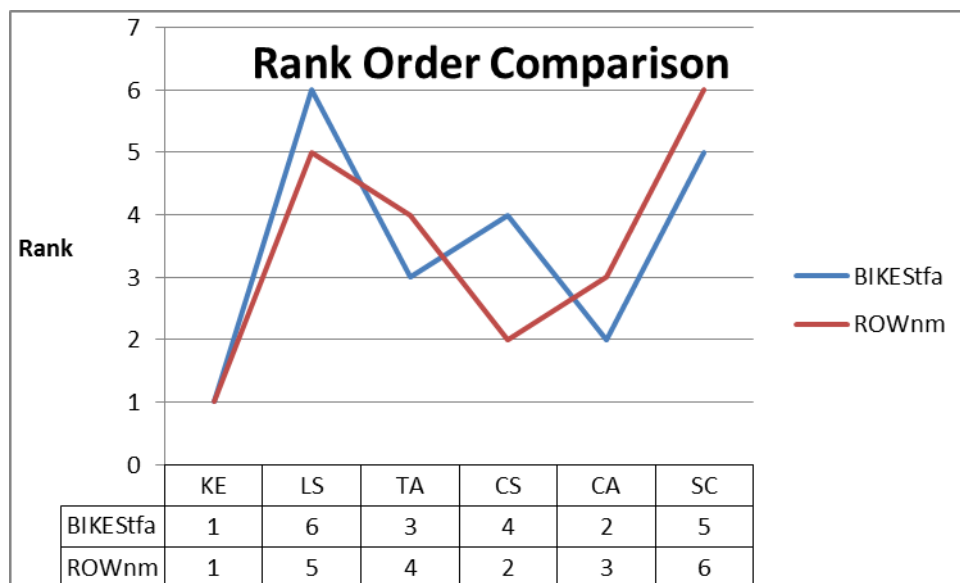


Figure 5-86. Rank Order Comparison of Bicycles To/From/On and Right-of-Way (ROW) for Bicycles and Pedestrians

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; BIKEStfa = bicycles to, from, along street per observer minute; and ROWnm = % of street right-of-way dedicated to bicycle and pedestrian use.

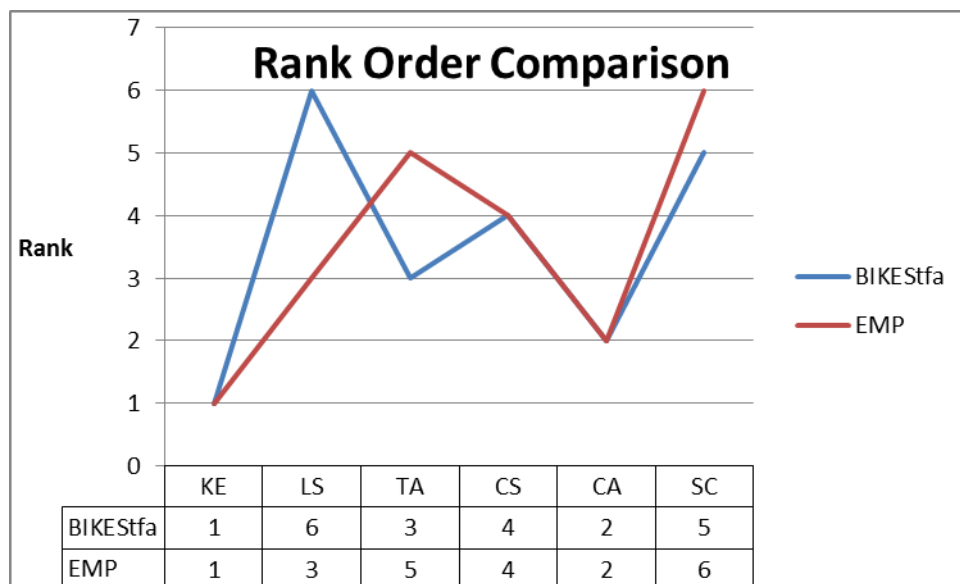


Figure 5-87. Rank Order Comparison of Bicycles To/From/On and Employment

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; BIKEStfa = bicycles to, from, along street per observer minute; and EMP = employment within .25 mile or .4km of street centerline.

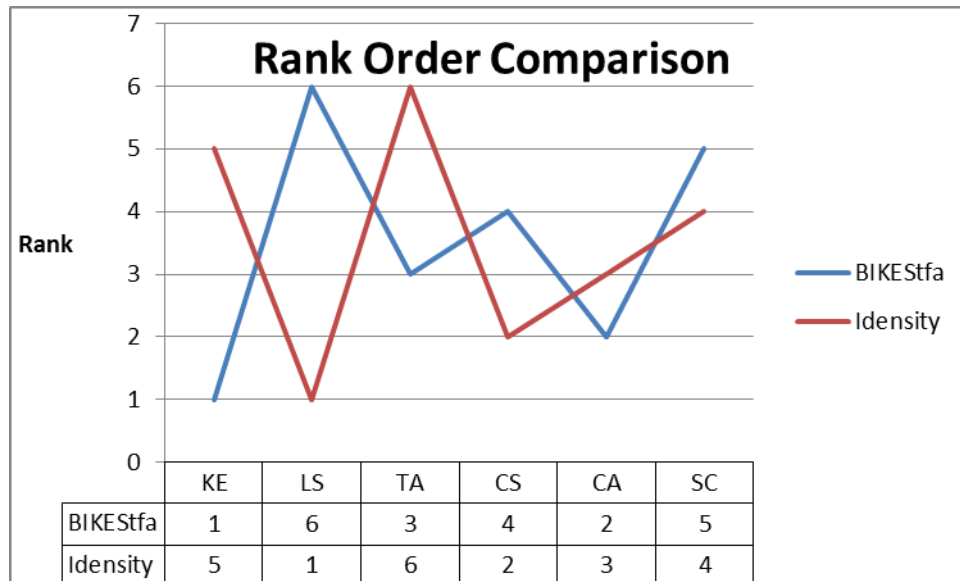


Figure 5-88. Rank Order Comparison of Bicycles To/From/On and Intersection Density

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; BIKEStfa = bicycles to, from, along street per observer minute; and Idensity = # of intersections within and from either end .25 mile or .4km of street centerline.

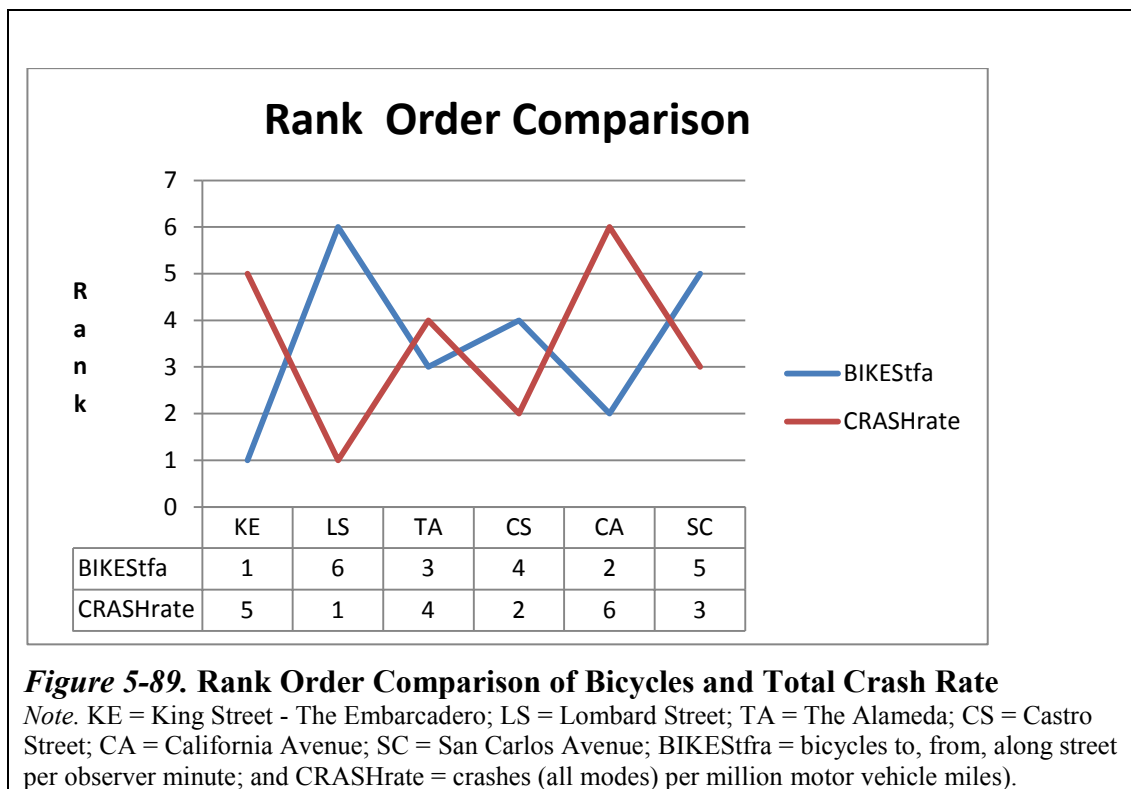
How are subjective perceptions of safety and comfort and objective indicators of safety associated with the amount of cycling on a street? There were no strong associations between the ranks by street in the amount of cycling with ranks in several objective and subjective measures. These included correlation with street ranks in the Bicycle Safety Index and both proportions of very safe and very comfortable survey responses. There was, however, a strong and statistically significant ($p = .02$) inverse association between street ranks by amount of bicycling and total crash rate for all modes of travel. To the extent that the crash rate reflects these hazards, cyclists seem to be aware of and responsive to the traffic hazards facing all street users. Table 27 and Figure 89 display this relationship.

Table 5-27

Spearman's Rank Order Test Results for Strength of Association Between Ranks of Bicycles To/From/On and Ranks of Street Safety and Comfort: Strongest Association

Pedestrian presence/ Test conditions	Compared to: (street context variable)	RS statistic =	2-tailed test p =
N = 6, DF = 4 2-tailed test			
	CRASHrate	-.89	.0188

Note. BIKEStfa = bicycles to, from, along street per observer minute and CRASHrate = crashes (all modes) per million motor vehicle miles).



Associations with public transport patrons activity and presence.

Ranking by public transport patronage, not surprisingly, was strongly associated with ranking by street in the amount of transit service provided, street environs population, and the sum of street environs population and employment. All of these associations were statistically significant. There was also a clear, but less strong and not statistically significant, association between transit use ranking and street ranks in employment. A negative association was apparent between rank of streets by public transport boardings and rank by amount of retail frontage, although

it was far from statistically significant and not easily understood. The association of public transport demand and transit service offered echoes findings by Kohn (2002), Taylor and Fink (2002), Chu (2004), and Cervero et al. (2009). The findings on the importance of population and employment confirm research by Taylor and Fink (2002), Johnson (2003), Chu (2004), Kuby et al. (2004), and Cervero et al. (2009). These results are in Table 28 and Figures 90 through 94. It is important to note that King Street - The Embarcadero not only has the highest level of transit service, it also provides the only continuous, dedicated public transport right-of-way space among the six street sections studied in this dissertation research.

Table 5-28

Spearman's Rank Order Test Results for Strength of Association Between Ranks of Transport Boardings and Ranks of Street Context Metrics: Strongest Associations

Pedestrian presence/ Test conditions	Compared to: (street context variable)	RS statistic =	2-tailed test p =
N = 6, DF = 4 2-tailed test			
	TRon	-.94	.0048
	POP	.89	.0199
	POPEMP	.83	.0416
	EMP	.66	.1562
	RETfront	-.60	.2080

Note. PTboard = public transport boardings; POP = population within .25 mile or .4km of street centerline; POPEMP = population and employment within .25 mile or .4km of street centerline; EMP = employment within .25 mile or .4km of street centerline; RETfront = retail frontage, linear feet per mile or km; and TRon = amount of public transport service on a street.

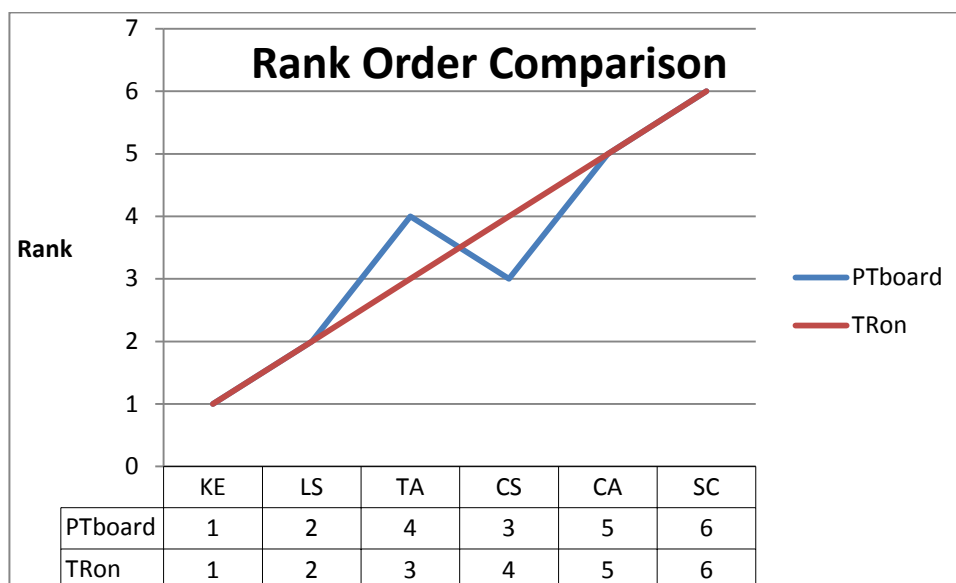


Figure 5-90. Rank Order Comparison of Transit Boardings and Public Transit Service Along Street

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS= Castro Street; CA = California Avenue; SC = San Carlos Avenue; PTboard = public transport boardings; and TRon = amount of public transport service on a street.

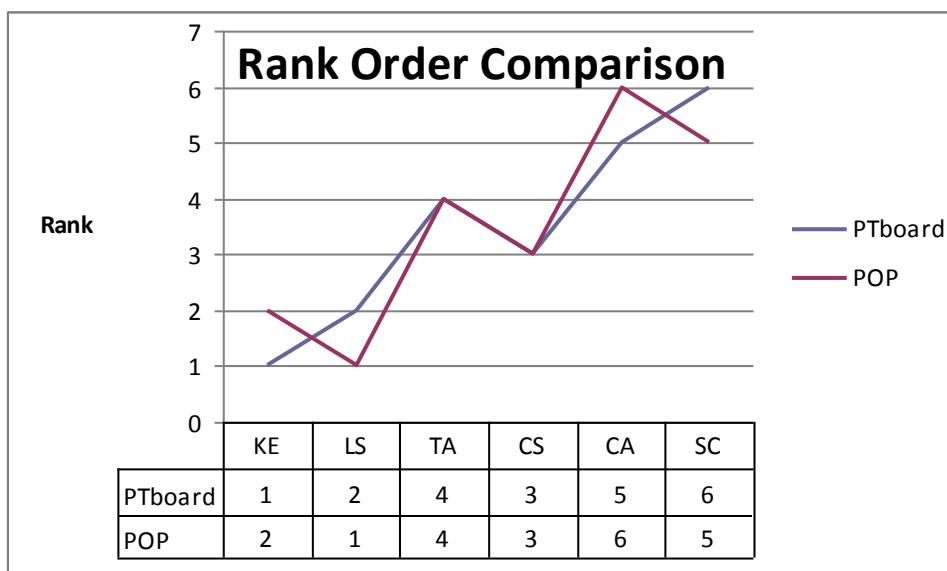


Figure 5-91. Rank Order Comparison of Transit Boardings and Population

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PTboard = public transport boardings; and POP = population within .25 mile or .4km of street centerline.

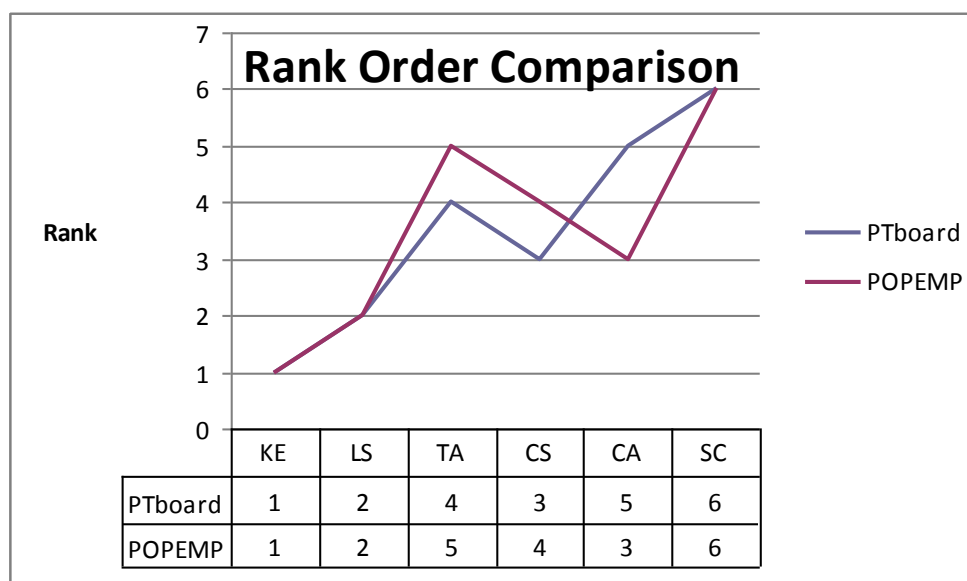


Figure 5-92. Rank Order Comparison of Transit Boardings and Employment & Population

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PTboard = public transport boardings; and POPEMP = population and employment within .25 mile or .4km of street centerline.

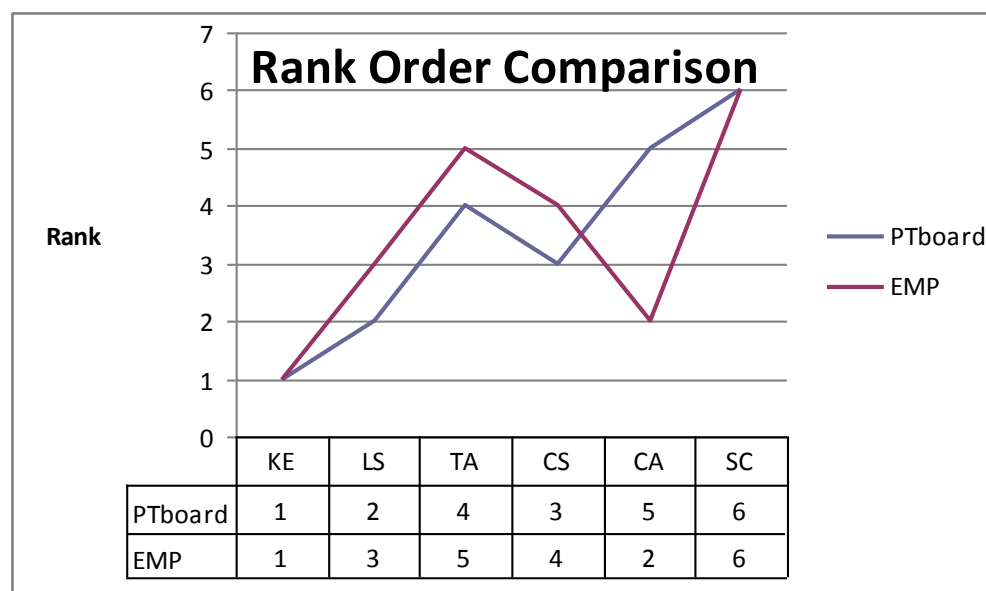


Figure 5-93. Rank Order Comparison of Transit Boardings and Employment

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PTboard = public transport boardings; and EMP = employment within .25 mile or .4km of street centerline.

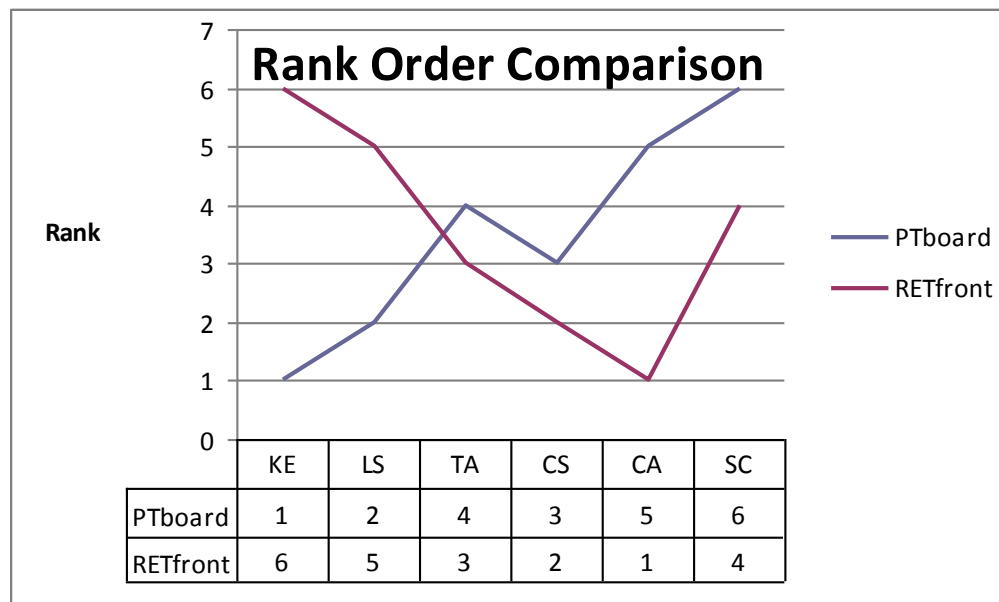


Figure 5-94. Rank Order Comparison of Transit Boardings and Retail Frontage
Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; PTboard = public transport boardings; and RETfront = retail frontage, linear feet per mile or km.

A Comprehensive Assessment of Six Streets for Activity, Sustainability

This section returns to the six streets for a comparative evaluation across dimensions of activity and sustainability.

Conclusions.

A comprehensive, multiple measure assessment of the six street segments presented in this section needs both words and some helpful images to summarize and consolidate the results. The next chapter discusses the meaning of these findings. This section will highlight salient results and conclude with some interpretive, albeit sometimes subjective, comments of my own.

Overview of findings.

The task of this research has been to investigate what makes arterial streets “active” and “sustainable”. Pursuing this investigation has required mixed-methods research, from detailed observations, photographic analysis, counting pedestrians and cyclists to conducting focus groups and surveying street users, as well as reflections on the data and information gathered. There are two broad categories of assessment results. The first is street user and businessperson appraisal achieved via self-completed surveys, focus group sessions, and visual assessment exercises. The second category is comparative street metrics. In each category, there are clear

differences among and between streets. Frequently, these differences reflect favorably on the two test or study streets, in contrast to the four control streets. Because streets, like cities and those who live in them, are complex entities, the picture is not always clear and the distinctions are not always crisp. Nevertheless, the research findings reveal a convincing pattern: the two test streets are more sustainable and more active than were each pair of control streets. A mosaic of colors in the following pages reveals this pattern.

Comparative metrics.

The two test or study street sections, King Street - The Embarcadero and Castro Street, compared favorably to the four control streets on the set of outcome variables. Almost across the board, the two exemplary streets had more pedestrian and bicycle presence and more transit patrons than their companion streets. Table 29 displays these comparisons for both the Big City and the Small City cohorts.

Table 5-29

Traffic Signal Snapshot of Outcome Variables by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
Pedestrians along	Green	Yellow	Red	Green	Yellow	Red
Pedestrians across	Yellow	Green	Red	Green	Yellow	Red
Total pedestrians	Green	Yellow	Red	Green	Yellow	Red
Pedestrian interactions	Green	Yellow	Red	Green	Yellow	Red
# People involved in interactions	Green	Yellow	Red	Green	Yellow	Red
Pedestrians standing	Green	Yellow	Red	Yellow	Green	Red
Pedestrian sitting	Yellow	Red	Green	Green	Yellow	Red
Stationary pedestrians	Green	Red	Yellow	Green	Yellow	Red
Pedestrian presence	Green	Yellow	Red	Green	Yellow	Red
Bicycles to/from/along	Green	Red	Yellow	Yellow	Green	Red
Bicycles across	Green	Yellow	Red	Green	Yellow	Red
Total bicycles	Green	Red	Yellow	Yellow	Green	Red
Total non-motorized volume	Green	Yellow	Red	Green	Yellow	Red
Daily transit boardings	Green	Yellow	Red	Green	Yellow	Red

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street. Pedestrian presence is the sum of pedestrians walking along and across a street and people standing or sitting along a street.

Right-of-way apportionment findings also favor the two test streets. Street design to reserve space for non-motor vehicle use was an essential characteristic that defined each of these streets as exemplary. The measurable extent to which each did so in contrast to the other four streets is notable. With few exceptions, the right-of-way allocation on King Street - The Embarcadero and Castro Street was away from motor vehicle use and oriented more toward active and/or sustainable uses. Table 30 reveals these contrasts.

Table 5-30

Traffic Signal Snapshot of Right-of-Way Use by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
ROW % - motor vehicles (net)	Green	Red	Yellow	Green	Yellow	Red
ROW % - pedestrians (dedicated)	Green	Red	Yellow	Green	Yellow	Red
ROW % - non-motorized modes (dedicated)	Green	Yellow	Red	Red	Green	Yellow
ROW % - transit (dedicated)	Red	Green	Yellow	Yellow	Red	Green
ROW % - nature (permeable)	Yellow	Red	Green	Yellow	Green	Red
ROW % - tree canopy	Yellow	Red	Green	Yellow	Green	Red

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; ROW = right-of-way; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street.

As summarized in Table 31, population and employment densities were generally higher or as high on each of the two test or study streets than on the two control streets in each cohort. If density matters for street activity and sustainability, which it clearly seems to in this study (and in much of the published research), King Street-The Embarcadero and Castro Street had the advantage of having sufficient numbers of people living and/or working nearby to achieve a sort of critical mass.

Table 5-31

Traffic Signal Snapshot of Socio-economics by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
Population within .25 mile, .4 kilometer radius	Yellow	Green	Red	Green	Red	Yellow
Employment within .25 mile, .4 kilometer radius	Green	Yellow	Red	Yellow	Green	Red
Employment & population within .25 mile, .4 km	Green	Yellow	Red	Yellow	Green	Red

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street.

Outdoor seating was generally more available on the test or study streets than on the two control streets in each cohort. One exception was the more limited provision of outdoor public benches on Castro Street. Extensive informal seating designed into the streetscape and by far the largest number of sidewalk café chairs in the entire group of six street segments compensated for this deficiency, however. This finding affirms research on the importance of a variety of seating opportunities, including informal ones, for active urban spaces (Whyte, 1980; Gehl, 1987; Marcus and Francis, 1997; Francis, Koo & Ramirez, 2010). Table 32 details the distinctions among streets in seating accommodations.

Table 5-32

Traffic Signal Snapshot of Outdoor Seating by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
Outdoor café chairs per mile	Yellow	Red	Green	Green	Yellow	Red
Outdoor public benches per mile, total	Green	Red	Yellow	Red	Green	Yellow
Outdoor public benches per mile, transit	Green	Red	Yellow	Green	Green	Red
Subjective rating of informal outdoor seating	Yellow	Red	Red	Green	Yellow	Red

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street. Ties are indicated by repeated colors.

Public transport services and facilities were more available to King Street - The Embarcadero and Castro Street than to the pair of comparison streets for each. One exception was in provision of transit stops. In the case of King Street-The Embarcadero, the large capacity of light rail platforms and signalized crosswalks to and from each compensated for the limited number (two) of transit stops on the street. In the case of Castro Street, the proximity of light rail and commuter rail platforms and a turnaround for connecting buses at the downtown Mountain View transit center compensated for fewer bus stops than on either California Avenue or San Carlos Avenue. Table 33 presents comparisons on public transport services and facilities across each street cohort.

Table 5-33

Traffic Signal Snapshot of Public Transport Services and Facilities by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
Daily transit frequency	Green	Yellow	Red	Green	Yellow	Red
Daily transit frequency, adjacent	Yellow	Green	Red	Green	Yellow	Red
Daily regional rail frequency, adjacent	Yellow	Red	Green	Green	Red	Yellow
Transit stops	Red	Yellow	Green	Red	Yellow	Green

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street.

Results for motor vehicle operations, in contrast, appear mixed. While the motor vehicle operating environment on Castro Street compares favorably to that of its two control streets as regards motor vehicle presence and operations, the same is not true for King Street-The Embarcadero. Table 34 shows this contrast. This result has support in the work by Lillebye (2007), showing that comparatively high motor vehicle traffic volumes could co-exist with a lot of pedestrian activity and not necessarily preclude a vibrant street environment. Many great streets around the world, from Robson Street in the West End of Vancouver to the Avenue des Champs-Élysées in Paris, demonstrate this co-existence. Nevertheless, the results of this research show that from a human viewpoint (as expressed in surveys of street users and business people, as well as focus group discussions), too much traffic and too much vehicle speed detract from street sustainability.

Table 5-34

Traffic Signal Snapshot of Vehicle Operations by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
85% Motor vehicle speeds, mid-section (MPH)	Yellow	Green	Red	Yellow	Green	Red
Annual average daily traffic (AADT)	Red	Yellow	Green	Yellow	Green	Red
% Commercial trucks in vehicle stream	Red	Green	Yellow	Green	Red	Yellow

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street. Ties indicated by repeated colors.

As presented in Table 35, the two exemplary street segments do not both fare better than their respective comparison streets in street frontage and streetscape attributes. While Castro Street compares favorably to San Carlos Avenue on these dimensions, King Street - The Embarcadero does not compare well to either The Alameda or Lombard Street. These findings run counter to the expectations expressed by urban designers about the importance of “path content” (Southworth, 2005) and in other work by urban planning and urban design scholars (Rapoport, 1987; Porte and Renne, 2005; Ewing, et. al, 2009). The next chapter will explore the reasons for and implications of this counter-intuitive result.

Table 5-35

Traffic Signal Snapshot of Frontage Attributes by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
% Frontage gaps	Red	Yellow	Green	Yellow	Red	Green
%, "Green gaps"	Green	Red	Red	Red	Red	Green
% Pedestrian buffer (at street grade)	Red	Yellow	Green	Red	Yellow	Green
Retail frontage	Red	Yellow	Green	Yellow	Green	Red
Restaurant frontage	Yellow	Green	Red	Green	Yellow	Red
Restaurant & retail frontage	Yellow	Green	Red	Yellow	Green	Red
Vacant street frontage	Red	Green	Red	Yellow	Green	Red
# Doorways	Red	Green	Yellow	Yellow	Green	Red
"Active"/"transparent" windows	Red	Yellow	Green	Yellow	Green	Red

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an "active" and/or "sustainable" street; yellow = the median value conducive to an "active" and/or "sustainable street"; and red = the lowest value conducive to an "active" and/or "sustainable" street. Ties indicated by repeated colors.

Findings for the set of bicycle and pedestrian context variables reveal a "checkerboard" pattern in which no street in either cohort is distinctive. Table 36 shows this scattered assessment mosaic. The next chapter addresses the possible reasons for these unexpected findings, as well as the influence of street frontage and streetscape.

Table 5-36

Traffic Signal Snapshot of Bicycle and Pedestrian Context by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
Pedestrian lateral connections	Red	Yellow	Green	Red	Yellow	Green
Commercial driveways	Green	Red	Yellow	Green	Red	Yellow
Crosswalks across	Yellow	Green	Red	Yellow	Green	Red
Crosswalks along	Red	Yellow	Green	Red	Yellow	Green
Signalized crossings	Yellow	Green	Red	Yellow	Red	Green
Total crosswalks	Red	Green	Yellow	Red	Green	Yellow
Bike racks	Green	Yellow	Red	Yellow	Green	Red
Intersection density	Yellow	Green	Red	Green	Yellow	Red

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street.

Comparative metrics for traffic safety represent a split decision or bimodal result for the test or study streets. While King Street - The Embarcadero compares well to its control pair of street sections, Castro Street lags behind the two other Small City arterial streets. Yet, Castro Street users perceive it as a comparatively safe street. The relationships between objective data and subjective perception of street safety, as discussed in Chapter 2, are sometimes contradictory. Chapter 6 will return to this theme in offering interpretations of the meanings of this contradiction. Table 37 shows traffic safety comparisons.

Table 5-37

Traffic Signal Snapshot of Traffic Safety by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
Crashes	Yellow	Red	Green	Yellow	Green	Red
Crash rate	Green	Red	Yellow	Red	Green	Yellow
Casualties	Yellow	Red	Green	Yellow	Green	Red
Casualty rate	Green	Red	Yellow	Red	Green	Yellow
Bicycle and pedestrian crashes	Yellow	Red	Green	Yellow	Green	Red
Bicycle and pedestrian crash rate	Green	Red	Yellow	Red	Green	Yellow
Adjusted bicycle pedestrian crash rate	Green	Red	Yellow	Red	Green	Yellow

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street.

Street user’s assessment.

Street user’s survey respondents perceived Castro Street and King Street - The Embarcadero more favorably than the two comparison streets in each cohort. People viewed each of the test streets as comfortable, attractive, and comparatively safe. The survey comments and focus group dialog were in accord with the multiple-choice survey results on these points. The tone of these commentaries and dialogs was also strikingly more appreciative of King Street - The Embarcadero and Castro Street in comparison to the control streets. Table 38 below shows that the two exemplary streets won plaudits from street users.

Table 5-38

Traffic Signal Snapshot of User Appraisal by Street

Metric	Street					
	K E	L S	T A	C S	C A	S C
Very comfortable	Green	Red	Yellow	Green	Yellow	Red
Very safe	Green	Red	Yellow	Green	Yellow	Red
Very attractive	Green	Red	Yellow	Green	Yellow	Red
Very convenient	Green	Red	Yellow	Green	Yellow	Red
Very active	Yellow	Green	Red	Green	Red	Yellow
Very important	Yellow	Red	Green	Red	Green	Yellow

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street. Ties indicated by repeated colors.

As with street user’s survey appraisal for attractiveness, King Street - The Embarcadero and Castro Street also were rated highly in the visual assessment exercise, although the former received the same average grade as one of its control streets. Table 39 presents these findings.

Table 5-39

Traffic Signal Snapshot of Visual Assessment by Street

Metric	Street					
	KE	LS	TA	CS	CA	SC
Average score	Green	Red	Green	Green	Yellow	Red

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; green = the value most conducive to an “active” and/or “sustainable” street; yellow = the median value conducive to an “active” and/or “sustainable street”; and red = the lowest value conducive to an “active” and/or “sustainable” street. Ties indicated by repeated colors.

Comparative metrics for traffic safety represent a split decision or bimodal result for the test or study streets. While King Street - The Embarcadero compares well to its control pair of street sections, Castro Street lags behind the two other Small City arterial streets. Yet, Castro Street users perceive it as a comparatively safe street. The relationships between objective data and subjective perception of street

safety, as discussed in Chapter 2, are sometimes contradictory. Chapter 6 will return to this theme in offering interpretations of the meanings of this contradiction. Table 37 shows traffic safety comparisons.

The focus group results, although more difficult to summarize in tabular form, generally mirrored those of the street user's survey. The topics discussed, the terms used, and the tone of the focus group dialogs reflected a greater degree of satisfaction, even enthusiasm, with the two test or control streets than with their two counterparts in each subset of streets. Similarly, the business survey results confirmed that the commercial conditions of King Street - The Embarcadero and Castro Street were comparatively favorable.

Measures of motor vehicle dominance.

Broadly, streets can move cars and/or accommodate people engaged in activities outside of cars. In a similarly dichotomous sense, motorized travel on streets can be by private vehicles or through access to public transport. Ratios of car drivers to either the number of people along the street out of cars or the number of people boarding public transit measure the extent of car domination of the street environment.

People engaged in out-of-car activities may be walking or cycling along or across a street. They may also be merely sitting or standing along the street. In all of the categories, the presence of people outside of motor vehicles stakes a claim for street right-of-way. Drivers stake a competing claim. It is in this sense that cars, to recall the memorable words of Jane Jacobs (1961), "compete with other uses for space and convenience" (p. 349).

Figures 95 and 96 reveal the extent of car domination of each of the six streets, the first as a ratio of car drivers to people out of cars and the second as a ratio of car drivers to people boarding public transport. The results confirm that the exemplary street segments are comparatively less car-dominated. Even in the case of the near identical ratios of drivers to street users out of cars for Castro Street and California Avenue, the former attains this virtual tie despite the latter being a dead-end street with about one-fifth less traffic and 15% slower 85th percentile speeds.

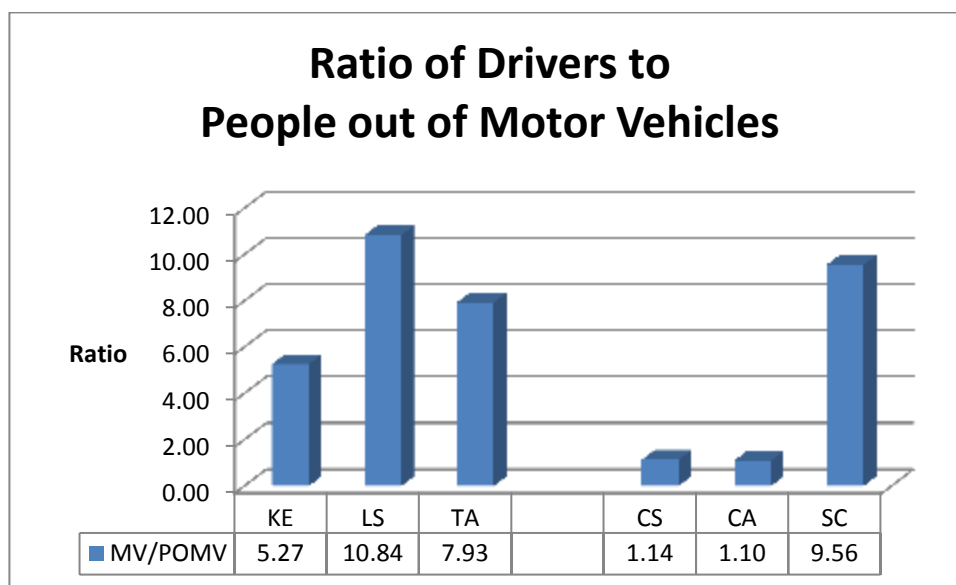


Figure 5-95. Ratio of Drivers to People out of Motor Vehicles: The First Measure of Car Domination

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; MV = Motor vehicles; and POMV = people out of motor vehicles.

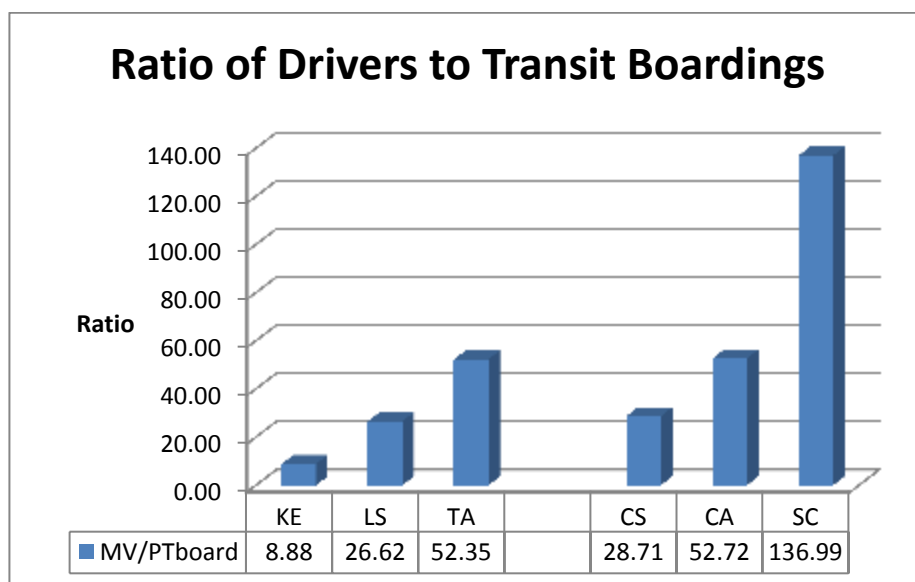


Figure 5-96: Ratio of Drivers to Public Transport Boardings: The Second Measure of Car Domination

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; MV = Motor vehicles; and PTboard = public transport boardings.

My own assessment.

What is my own assessment of these streets based on personal experience using and studying each of the six street segments? As shown in Table 40, I give higher marks to each of the test or study streets than to the control streets. King Street-The Embarcadero and Castro Street are simply more lively, more attractive and (in their individual ways) more interesting than the streets to which they have been compared in this research. A more judicious, in fact felicitous, allocation of right-of-way space decided for both of these streets than for their companion control streets. As a result, King Street - The Embarcadero is excellent for walking, cycling, and using public transport. Castro Street is superb for café dining, people watching, and strolling. Each street is a distinctive and effective link from a traffic perspective and a special place too. These streets seem to have effectively balanced passage and place.

Table 5-40

My Olympic Medal Appraisal of Attributes by Street

Metric	Street					
	KE	LS	TA	CS	CA	SC
Walkable	Gold			Silver	Gold	
Bikable	Gold			Gold	Silver	
Transit-Friendly	Gold		Silver	Gold		
Trees & Nature	Silver		Gold			Gold
Active	Silver			Gold	Gold	
Attractive	Gold		Gold	Silver		

Note. KE = King Street - The Embarcadero; LS = Lombard Street; TA = The Alameda; CS = Castro Street; CA = California Avenue; SC = San Carlos Avenue; gold = the value most conducive to an “active” and/or “sustainable” street; silver = the value that is second most conducive to an “active” and/or “sustainable street”; and bronze = the value that is third most conducive to an “active” and/or “sustainable” street.

Table 5-40

What can we learn from this detailed analysis of user perceptions and street conditions? Drawing on the findings in this chapter, Chapter 6 offers insights, draws some tentative conclusions as well as identifying the implications for public policy. As research on any complex subject always raises new questions, Chapter 7 discusses suggestions for further research. This dissertation has explored much ground in pursuit of an answer to the question, “What makes arterial streets

sustainable and active?” The pages to follow provide a further narrative of and signposts for this journey.

CHAPTER 6

CONCLUSION: EXPECTATIONS, RESULTS, AND IMPLICATIONS FOR PUBLIC POLICY

Research Approach

The findings discussed in Chapter 5 were arrived at through use of a mixed-methods research strategy, which has been described as using “qualitative and quantitative data collection and analysis techniques in either parallel or sequential phases” (Tashakkori & Teddlie, 2003, p. 11). Chapter 3 comprises a detailed description of these methods. The advantage of using a mixed-methods approach is that, just as in navigation, they provide a kind of triangulation using “multiple reference points to locate an object’s exact position” (Jick, 1979, p. 602). In this research the triangulation is of two types; both are employed to answer research questions. The first is in collection and analysis of both quantitative and qualitative data and information. The second is use of both primary and secondary data and information collected in the course of the research.

The framework for the research is a 1:2, compare and contrast design, inspired by the Bosselmann et al. (1999) study of multi-way boulevards. This design created the opportunity to examine in depth prototypes of two kinds of street, the complete street and the context-sensitive street, each in contrast to a pair of more conventional street sections. This framework also made it possible to compare and contrast the larger and smaller city contexts for these streets. The economy of the 1:2 research design facilitated study in detail of a manageable number of street sections. The result was an illumination of many differences among streets that otherwise shared many common attributes. Reliance on both nonparametric statistics and qualitative methods was required in trading off breadth in sample size for depth in detail with this research design.

My research strategy was informed by my own insights as a street user, transport planning practitioner, and urban planning scholar. There is no substitute for spending a lot of time actually using the streets that one is also studying. This is especially true if the street use is by all the available modes of travel and includes taking time for “outdoor stays”, for example people watching from a sidewalk café or counting those pedestrian interactions that are so integral to lively streets (Gehl, 2006).

My expectations were that the study or test streets would be more active and more sustainable environmentally, economically, and socially than the control streets to which they were being compared. In other words, that King Street – The Embarcadero and Castro Street would have more pedestrian activity, transit use, and commercial appeal, as well as being safer to use and more livable as a human environment compared to the pair of control streets against which they were being measured. A further expectation was that the two test streets (taken together as a sub-set) would be more successful as active, sustainable streets (than the four control streets as a sub-set). Success in this context can be defined as more closely approximating the working definition of a sustainable arterial street, as proposed in the “Defining a Sustainable Arterial Street” section of Chapter 2 of this dissertation: “A sustainable arterial street gives priority to energy efficient, low or no emission modes of transport; supports social and economic vitality; ensures traffic and social safety; incorporates natural elements; and creates visual interest for its users.”

A singularly important expectation in this research effort was that re-allocation of street right-of-way from private motor vehicles to pedestrians, cyclists, public transport, and nature would contribute to making streets both more active and more sustainable. Similarly, this research began with the notion that urban design and streetscape qualities, street design, as well as how the street front was used, could also influence activity on and the sustainability of streets. While the findings of this research discussed in Chapter 5 provide extensive and relatively strong evidence on street activity and sustainability, the nature of research on small samples does not permit absolutely conclusive results in a statistical sense. However, such research can offer well-grounded support to hypotheses about the nature of sustainable, active streets. The research in this dissertation has achieved this result.

Expected, Intuitive Results

A signal and expected result was that street right-of-way allocation matters. The two test street sections that had the highest proportion of right-of-way given over to uses other than the movement of private motor vehicles were also the most active. Both streets featured allocation of a substantial proportion of right-of-way to sidewalks, those mundane facilities, often taken for granted, that have been described as “multiuse environments” rather than “pure pedestrian thoroughfares” (Loukaitou-Sideris & Ehrenfeucht, 2010, p .22). In the case of King Street – The Embarcadero, wide sidewalks serve commuting pedestrians and cyclists, as well as recreational

walkers and joggers. Along Castro Street, sidewalks afford room for café patrons, strollers, window shoppers, and people waiting to board a bus. More space was in fact linked to more use of the two streets for these activities.

Another research expectation was that restaurants along a street front activate the street. The finding of a nearly perfect rank order correlation between the amount of pedestrian presence and the extent of street front in restaurant use met that expectation. In the course of many visits to each of the six streets studied in this dissertation, I was struck by just how much activity these businesses can generate. A lively scene is created by prospective patrons scanning menus posted on restaurant windows or walls, others queued up on the sidewalk waiting to be seated inside or out, and still more eating and chatting at sidewalk cafés.

This research also began with the idea that public transport, especially rail transit, can activate a street and support street sustainability. This expectation was also met. Each of the test streets had the most public transit service, as well as the most pedestrian presence in their respective cohorts. Both King Street – The Embarcadero and Castro Street benefit from the proximity of light rail as well as commuter rail services. Many appreciative focus group and open-ended survey comments about transit availability on and near each street described its importance to street users. I was impressed by the contribution that people walking to and from and waiting at transit stops make to street activity levels. Prospective public transport patrons waiting for a train or bus interact with others at the stop or on the platform. The stream of transit users walking to and from transit stops animates the scene on the sidewalks and crosswalks they use. Some of these patrons stop to patronize stores and restaurants, or enter offices to begin or resume work, after de-boarding.

There is also some evidence that street design itself appears to matter. Both test streets had far fewer commercial driveways than any of the four other street sections studied. Castro Street had the fewest through lanes for motor vehicle travel and King Street – The Embarcadero tied for the fewest in their respective street cohorts. An index of such design variables as ranks of pedestrian connections through to nearby streets, as well as inverse ranks of number of driveways and number of signalized crossings, was positively associated with ranks of pedestrian presence, although not strictly statistically significantly so. Notably, while there were street user's comments in focus groups and on-line surveys in praise of easier pedestrian navigation on both test streets, there was little, if any, such praise for the

control streets. This finding testifies to the importance of street design for some users of these exemplary streets.

If perceptions of comfort and safety for walking or bicycling on a street are necessary, though not sufficient, conditions for actually doing so, King Street – The Embarcadero and Castro Street meet those conditions. Each street segment was viewed favorably for both qualities in street user’s survey ratings, as well as in comments made in both surveys and focus groups. There was a gap, however, between perception of safety and objective information on safety. The disconnection discordance between the two will be discussed in the next section of this Chapter.

Results from this study provide evidence to confirm earlier research findings that for pedestrians and cyclists there is indeed “safety in numbers” (Jacobsen, 2003). Three streets, Castro Street, King Street – The Embarcadero, and California Avenue, for example, contributed almost three-quarters of the total pedestrian volume counted for the six streets studied in this dissertation. The same three streets represented less than one-quarter of the total crashes involving pedestrians. The two test streets had just over half of the total pedestrian volume observed for the entire set of six streets, but only little more than one-fifth of the pedestrian crashes. Similarly, the two test streets plus The Alameda represented just over four-fifths of the bicycle volume, but only about half of the crashes involving cyclists. The exemplary streets diverged on this indicator, however, as King Street – The Embarcadero had a lower proportion of bicycle crashes than bicycle volume, but not so for Castro Street.

What about attractiveness? These results were also about as expected. Castro Street was deemed more attractive than the two Small City control street segments in street user’s surveys, as well as in visual assessment exercises. King Street – The Embarcadero also did well on both, although the visual assessment rating for this street was exactly equal to one of the Big City control streets, The Alameda. The advantage of the test streets on their appearance and appeal was emphasized in comments made on user’s surveys, as well as in focus group sessions.

Business survey respondents provided evidence that the two study streets combined provided a better business environment than did the control streets combined. The advantage given King Street – The Embarcadero over Lombard Street, the Big City arterial street with the second most favorable assessment by business people was, however, not statistically significant. In contrast, Castro Street’s advantage over second-rated San Carlos Avenue was statistically significant.

One hoped-for and largely realized expectation was that a “context-sensitive” main street can be more active and more sustainable than a low-traffic-volume, low-motor-vehicle speed, but conventionally designed main street. Another largely realized expectation was that an urban arterial designed as a “complete street”, although tasked with being the surface street extension of an urban freeway, can be more active and sustainable than an urban arterial similarly tasked but conventionally designed. The two test streets had more pedestrian presence and pedestrian interactions, as well as more public transport use than did each pair of street sections to which they were compared. Street user’s surveys and focus group assessment results also clearly favored King Street – The Embarcadero and Castro Street over their companion street sections.

Unexpected and/or Counter-Intuitive Results

An important expectation not realized in these research findings was that streetscape and street front design details make a discernible difference in street sustainability and activity, largely through enhancing the pedestrian environment. It is true that street users praised various urban and landscape design details on the test streets more often and more highly than the control streets in their survey and focus group comments. Nevertheless, this research did not contribute convincing evidence that these details helped differentiate between the test and control streets. The test streets had neither more tree canopy in their streetscape nor more windows or doors on their street front, for example, than did the control streets. Nor did the two exemplary streets, taken together, have less vacant built frontage or more continuous occupied street front than did the conventional streets.

These unrealized expectations may be due to the special features of individual streets within the small sample of street segments studied. King Street – The Embarcadero, for example, was designed to take advantage of gaps in the street front on the Bayside in order to afford street users some striking views of the San Francisco Bay. The Alameda has long been a street notable for trees and tree canopy over sidewalks. These trees have continued to thrive even as that street declined as a commercial and social space. Lombard Street has continuous street frontage and more windows and doors than King Street – The Embarcadero, yet much less pedestrian presence largely because of its intensely car-dominated environment. Streetscape and urban design variables may supplement, but cannot replace, the key

drivers of active, sustainable streets. These drivers include right-of-way allocation, street design, pedestrian-oriented land uses, and public transport provision.

Another unexpected or counter-intuitive finding was that intersection density in the environs of the test streets was not higher than that of the control streets; hence, it did not contribute to the differentiation between the more active, more sustainable study street sections and their conventionally designed counterparts. Similarly, the two exemplary streets did not have more pedestrian crossings or pedestrian lateral connections to other streets that facilitated pedestrian movement between the two than did the control streets. Again, this finding may be a function of the nature of the streets in the sample of street segments studied. Pedestrian connections on King Street – The Embarcadero, for example, are limited on the Bayside since this street traverses the waterfront. In addition, the design trade-off made for this boulevard was in favor of fewer, yet signal controlled and well buffered, pedestrian crossings. Lombard Street, in contrast, is embedded in a street grid network. As such, there are frequent signal controlled crossings because of this grid network and the frequency of important cross streets along the reach of the segment studied. As in the case of streetscape and urban design variables, street grid and pedestrian lateral connections may be valuable additions, but not the basic ingredients, in the recipe for active, sustainable arterial streets.

An important (as well as interesting finding) of this research was the apparent gap between street users' subjective perceptions of street safety as expressed in survey results and focus group comments and objective data on street crash history. This was most apparent for Castro Street. This street section was deemed by street users to be just as safe as low-traffic, low-speed California Avenue and much safer than the third Small City arterial street in this research, San Carlos Avenue. Nevertheless, on indicators such as number of crashes, crash rate, number of crash casualties, and casualty rate, Castro Street was less safe than California Avenue and about as unsafe as higher motor vehicle-volume and speed San Carlos Avenue. While Castro Street's performance was much better on the composite Pedestrian Safety Index and Bicycle Safety Index than on the other safety indicators and far safer than San Carlos Avenue on these two metrics, it still performed behind California Avenue on both of these measures.

Any perceived traffic safety risk of using Castro Street, as measured in street user's survey results, may simply be too low to influence street user attitudes or

behavior. It can be argued that perceived risk is a function of an individual's assessment of the probability of loss and his or her valuation of the importance of such a loss (Dowling, 1986, p. 198). A rate of one pedestrian crash per mile for every million pedestrians may be below the risk perception threshold of most Castro Street users. While the cyclist crash rate of about twenty-five per mile per million cyclists is certainly higher than the pedestrian crash rate, this affects far fewer Castro Street users, as most use the street on foot rather than by bike. Viewed objectively, the comparatively high bicycle crash rate on Castro Street is likely to be related to the restricted space for cycling in the absence of a bicycle lane or wide curb lane. Nevertheless, the subjective perception of traffic safety risk is low for most Castro Street users.

Comparatively higher motor vehicle speeds and lack of buffer areas on each side and in the middle of the street may affect both the perception of risk by pedestrians and empirical results manifest in pedestrian crash data. This would explain the comparatively poor performance of Lombard Street, The Alameda, and San Carlos Avenue on both subjective and objective indicators of pedestrian safety.

Finally, there were the confounding results on how active each of the streets was in the estimation of their users. Control streets with less pedestrian presence and activity than each of the test streets were considered to be very active by either a much greater or nearly the same proportion of street users than was the case for the King Street – The Embarcadero and Castro Street, respectively. Some street user's survey respondents, including several commenting on Lombard Street, did differentiate between activity caused by motor vehicles and activity caused by pedestrians. Nevertheless there seems to be an inherent ambiguity in the term "active" so that many people perceive the presence of a lot of motor vehicle traffic to be as much or more an indicator of the activity level of a street than the number of pedestrians, pedestrian interactions, and bicyclists.

There appears to be a degree of cultural conditioning here in two ways. First and most obvious is the apparent interpretation of a lot of motor vehicle movement as "activity". The second possible reason for the result is that people are conditioned by what they are familiar with, so that an objectively lesser amount of pedestrian and bicycle activity on the control streets is in the mind of regular users just as "active" as a larger amount of activity on the test streets. In other words, people are conditioned

by expectations and experiences, which do not necessarily concur with objective reality.

Contributions to the Literature

There is a pattern of findings in this research, produced through use of both quantitative and qualitative research tools, confirming the expectation that arterial streets can be re-designed successfully toward sustainability. The scientific consistency of results from such a multiple methods research effort, when achieved, strengthens confidence in their validity (Jick, 1979, p. 608).

These findings, expected or unexpected, have contributed to the scholarly literature. This research is the first detailed investigation of factors that may contribute to how active and how sustainable are arterial streets, whether these streets are “complete”, “context-sensitive”, or of a more conventional design. The use of extensive data sets and information sources, both primary and secondary, in the context of a mixed-methods research strategy and a 1:2 research framework is a first of its kind in assessment of arterial streets. Another first of its kind was the comparison of street physical characteristics, including allocation of street right-of-way and characteristics of street geometry, as well as both urban design and land use detail to street usage. This street usage studied was not only in terms of motor vehicles, public transport, and bicycles, but also in terms of pedestrian interactions and pedestrian presence.

This dissertation research is also unique in the extent to which nonparametric statistical procedures were employed in the study of streets. These procedures were needed because of the deep (in detail) but narrow (in number of streets) street sample frame. As a result, the research was able to analyze the most complete, comprehensive, and detailed dataset yet assembled for scholarly research on arterial streets.

This research is the first to delineate the apparent gap between street user perceptions of street safety and objective data on street crash history. In addition, findings from this dissertation on pedestrian and bicycle travel along arterial streets confirm that there does appear to be “safety in numbers”. This and other aspects of the research, as will be discussed in a section of the next Chapter, merit further scholarly exploration. Beyond these contributions to the scholarly record, does this research also have any implications for public policy?

Implications for Public Policy

How generalizable are these research results? Each of the six streets has idiosyncrasies. Surely, the broad sweep of Bay views and presence of a major league baseball stadium sets King Street – The Embarcadero apart. Castro Street’s fetching mountain views and close proximity to a commuter rail, light rail, and bus intermodal center make it an exceptional small city main street. The Alameda is walking distance away from an even more transit rich environment (San Jose’s downtown Diridon Station) as well as a major league ice hockey arena. California Avenue is located close to a major research and professional services center (the Stanford Research Park) and anchored by a commuter rail station. Moreover, it is also linked to a bicycle and pedestrian undercrossing connecting it to one of the most affluent neighborhoods on the San Francisco Peninsula. Both Lombard Street and King Street – The Embarcadero are unusual in being in effect surface street extensions of freeways. The section of San Carlos Avenue studied in this research is a bifurcated street, half suburban arterial and half downtown street in a small city.

Nevertheless, all six streets function as commercial arterials that provide varying degrees of link and place attributes to their users. The three Big City arterial streets are tasked, as are large number of such streets worldwide, with the job of supporting travel to and from urban centers. The three Small City arterials are clearly recognizable as main streets, once the dominant form of commercial street in North America and still an important street type. In their essentials, all six streets are analogous to innumerable other streets in the US and elsewhere.

These research findings suggest that thoughtful street design, including provision of complete and context-sensitive streets, can result in more active, more sustainable thoroughfares than has been the case with conventional, post-World War II arterial street design. This result can be accomplished both through retro-fitting of existing streets and design of new streets. Put another way, designs that seek to harmonize the “link” and “place” functions of arterial streets can yield satisfying results for streets users and communities. The research results produced strong evidence that there are tiers or circles of influence on and support for active, sustainable arterial streets. Chapter 7 presents a model or framework for thinking about the street characteristics within and the importance of each circle.

Evidence from this research also suggests that urban and suburban arterial streets can be redeemed through an inter-disciplinary design process, informed by

community engagement. Moreover, the built environment disciplines of engineering, transport planning, land use planning, and architecture need to collaborate in consultation with public health planners, just as in the era of urban planning before mass motorization transformed cities. The goal of this engagement and collaboration would be to produce street right-of-way plans that create multi-purpose, attractive, and safe environments for people. Consultation with street users is critical to inform the trade-offs in street right-of-way allocation, modal emphasis, street front apportionment, and in the design details that affect the look and feel of a street. Planning for supportive land use mix, densities, and site design needs to be part of any comprehensive effort to design or re-design arterial street corridors. In summary, this research largely affirms the new thinking in design guidance for context-sensitive major urban thoroughfares (Daisa, 2006).

Another and related policy implication is that street right-of-way allocation makes a difference in the link and place performance of arterial streets. Professional practitioners and policy makers need not pursue, as if in automatic pilot mode, the pattern of adapting streets and cities to the needs of motor vehicles, as has been the case from the early days of mass ownership of private cars (McShane, 1994). Instead, street rights-of-way can be shaped and re-shaped like clay. In this way, these “streets of clay” can become instruments for creating livable cities and suburbs, links and places for active, sustainable community life.

The value of such findings should not be underestimated in a world that is urbanizing⁹³ and motorizing⁹⁴ rapidly and often in ways that lead to streets designed to be diametrically opposed to the positive findings of this study. The results are of major guidance to cities throughout the auto-oriented developed world, in North America, Australia and other places. The sprawling, low-density cities are under both intense local and global pressure to be transformed into something more sustainable.

⁹³ An estimated 737 million people lived in urban areas worldwide in 1950. That number rose to nearly 3.5 billion by 2010 and is projected to be at 6.4 billion by the year 2050. Retrieved from the United Nations, Department of Economic and Social Affairs, web site: <http://esa.un.org/unup/>

⁹⁴ The world's motor vehicle fleet has grown an astonishing twenty-fold in the past sixty years, from an estimated 50 million in 1950 to approximately one billion in 2010. Retrieved from the Plunkett Research, Ltd. Web site: <http://www.plunkettresearch.com/automobiles%20trucks%20market%20research/industry%20overview> and from the World Resources Institute web site: <http://www.wri.org/publication/content/8467>

The enormous lengths of conventional arterial streets that exist across the USA alone constitute a new development frontier.⁹⁵

It is clear from scholarly work in sustainable urban transport (Kenworthy and Newman, 1999; Schiller et al., 2010) that such auto cities do need to increase development densities and provide quality public transport systems and more walkable environments. The vast swaths of often derelict and underutilized land that lie along so many arterial streets⁹⁶, often in the form of huge parking lots, present opportunities for large revitalization projects⁹⁷ and the generous widths of such streets provide a veritable treasure of opportunities for programs that seek to re-allocate street space in the way outlined in this thesis. The auto-oriented patterns of the developed world are being replicated at a truly alarming rate in the rapidly motorizing mega-cities in Asia, Latin America, and Africa. Interestingly, this is occurring in societies that have strong street culture traditions, but these are being overwhelmed in favor of patterns that this study identifies as the least sustainable. Thus the findings in this thesis can help to generate a larger urban policy discussion throughout the world that attempts to draw an urgent focus back on the need to create streets that are truly the lifeblood of communities, not high volume traffic sewers, which is the current trend.

The results from this research show that “streets of clay” can be molded to suit people and their communities. This is part of the on-going effort to re-balance urban transportation systems in support of more livable cities (Vuchic, 1999). The next chapter answers the research questions that began this inquiry. In doing so I present a model for what influences and supports active, sustainable arterial streets. I

⁹⁵ In 2008, there were 90,770 lanes miles of urban principal arterial (excluding limited access freeways and expressways) and minor arterial streets in the United States. Retrieved from the United States Department of Transportation, Federal Highway Administration web site: <http://www.fhwa.dot.gov/policyinformation/statistics/2008/hm43.cfm>

This is equivalent to more than twenty-eight times the distance between Portland, Oregon and Portland, Maine, namesake cities on opposite coasts of the continental United States. Retrieved from the United States of America Embassy Guide Web site: <http://www.usembassyguide.com/us-distance-chart/portland-oregon.html>

⁹⁶ Google Maps Street View provides users with a tool to easily audit the streetscape of arterial streets in many places worldwide. For a discussion of the reliability of these virtual audits, see Badland, Opit, Witten, Kearns, & Mayoa (2010).

⁹⁷ One notable example of such a project on the San Francisco Peninsula is the Grand Boulevard Initiative, an attempt to transform the historic El Camino Real and Mission Street corridor from Daly City to San Jose, California. Retrieved from the Grand Boulevard Initiative Web site: <http://www.grandboulevard.net/>

also offer ideas for future research to deepen scholarly understanding of these “streets of clay”.

CHAPTER 7
SUMMARY: RESEARCH QUESTIONS RE-VISITED,
CONTRIBUTIONS TO NEW KNOWLEDGE,
AND GUIDEPOSTS FOR FUTURE RESEARCH

Research Questions

This research began with a set of eight questions. The search for answers required an exploration of the scholarly record across several disciplines, from traffic engineering to urban design and transport planning to public health, among others. This quest also included data collection and analysis focused on six streets along the San Francisco Peninsula in California. The results contribute to scholarship and can help inform public policymaking about ways and means to create streets that meet community needs. The sections to follow summarize the responses the research yielded to each of these eight research questions

"Active" streets.

What are “active” streets and how can “activity” on streets be measured?

Active (or lively) streets offer opportunities for travel on foot and by bicycle, as well as afford an animated venue for social, commercial, and recreational activity (Mehta, 2006), as shown in Figures 1 and 2. Metrics used to gauge street activity in this research included counts of pedestrians walking along and across the street, pedestrian interactions and number of people involved in these interactions, pedestrians sitting and standing alongside the street, and bicyclists cycling along and turning onto or off of the street. Street users and business people were also asked for their opinions about the amount of activity on each street.



Figure 7-1. Pedestrians along Castro Street
Photograph by author.



Figure 7-2. Street Fair on Castro Street
Photograph by author.

The two exemplary or test streets, King Street – The Embarcadero and Castro Street had a great deal of activity: the two highest pedestrian counts, number of pedestrian interactions, and amount of people either walking or bicycling of the six street sections evaluated. Further, each had the highest number of pedestrians either sitting or standing in their respective big city and small city comparison cohorts. These objective data were corroborated by comments made by street users in surveys and focus groups. On King Street – The Embarcadero, one focus group participant observed, “There is a lot going on; people running, people mingling. That all feels pretty good.” A street user survey respondent noted that on the Castro Street, “outdoor seating and high pedestrian traffic create lots of opportunities for people watching; narrow streets and frequent crosswalks make it easy to navigate on foot.” Another wrote that the street was “focused on pedestrians and creates a sense of community.”

The term “active” when applied to streets, however, has a dichotomous meaning. Writing five decades ago, Jane Jacobs (1961) ascribed one meaning, that of liveliness of the people and the social life on a street, to “both its users and pure watchers” (p. 37). These users and watchers perform on what Jan Gehl (1989) called “... the largest stage in the city, and the most used” (p.17). Yet, streets can also be active as motor vehicle traffic conduits, busy links for vehicle movement in an environment inimical to pedestrian presence and social life along the traffic stream. One respondent to the Lombard Street user’s survey put it this way: “From a pedestrian point of view, very limited activity; from a vehicle point of view - too much activity, especially at commute hours.” Similarly, a respondent to The Alameda street user’s survey saw “lots of people in cars” but “not a lot of pedestrians, except shortly before and after Sharks games”. Even with the dichotomy inherent in the term, the two test streets were deemed by street user survey respondents to be more active in the human sense than were the four control streets.

Does continuous street (building) frontage contribute to “active” streets and, if so, how can its contribution be measured?

For Porta and Renne (2005) façade continuity, or the continuousness of the building façade such that it follows the line of sight is an indicator of “social urban sustainability”. Ewing and Handy (2009) define “enclosure” as “the degree to which streets ... are visually defined by buildings, walls, trees, and other vertical elements” (p. 75). While these ideas are appealing and intuitive, this research was not able

confirm the validity of their contribution to active, sustainable streets. The two test streets had either the highest or the second highest percentage of street frontage gap in their respective cohorts. There was little indication from street user's survey respondents or focus group participants of the role one way or the other of continuous building frontage in street activity and sustainability. One exception was a Castro Street user's survey respondent who praised the street for having "buildings that come right to the sidewalk". While it was clear that this factor was not a *sine qua non* of street activity, this research does not suggest that streets should be created with as many gaps as possible. What it does suggest is that while the weight of current research is on the side of continuous building frontage being a positive factor in active streets, its inadequacy can be compensated for by other factors in particular circumstances.

Street design and street function.

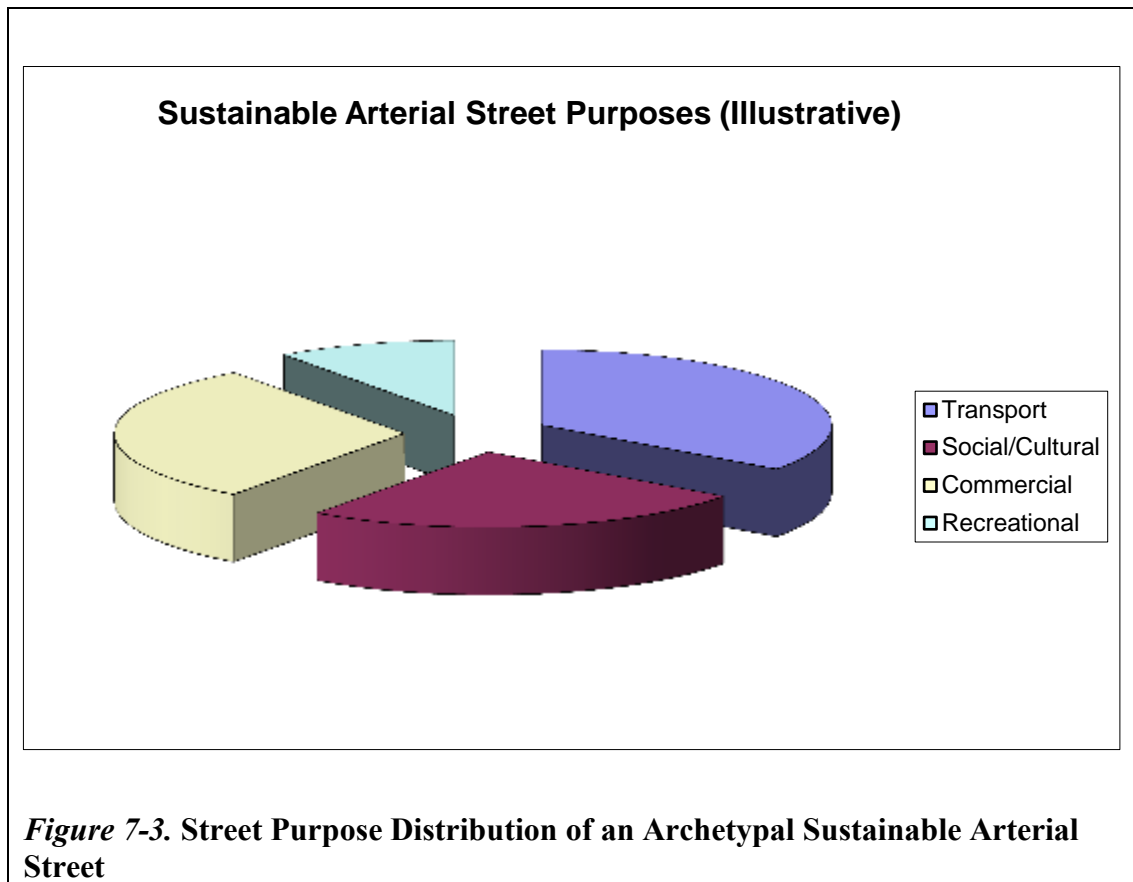
Does street design (geometry, partitioning of space) affect street use and, if so, how?

The European ARTISTS research initiative defined the sustainable arterial street as:

an arterial street whose physical and regulatory provision supports accessibility and social and economic activity while minimizing the immediate and longer term negative environmental impacts of vehicles, balancing or trading-off between the immediate street role and the urban system as a whole". [This requires] "a balance between keeping the traffic moving and providing space and time for other activities" (Svensson, 2004a, p. 7).

Figures 3 through 5 reveal how street purposes are balanced on three arterial street archetypes. The first archetype is the sustainable arterial street, which serves an array of purposes and offer transport choices to street users. As Figure 3 depicts schematically, transport does not dominate this type of street, as there is ample space for commercial, socio-cultural, and recreational purposes. In contrast, the purposes served by conventional arterial streets, which are shown schematically in Figure 4, lack balance. This type of street is dominated by the transport task, mostly in the form of movement of private motor vehicles. Figure 5 shows the extreme imbalance in an arguably pathological form of the conventional arterial street, the "sewers for the rapid movement of lumps of metal" (Whitelegg, 2011, p. 3). These illustrations

do not reflect just right-of-way space allocation. They are also an abstract measure of the dominance of the motor vehicle. This dominance can induce feelings of discomfort and vulnerability in pedestrians and cyclists and sever neighborhoods from each other.



Conventional Arterial Street Purposes (Illustrative)

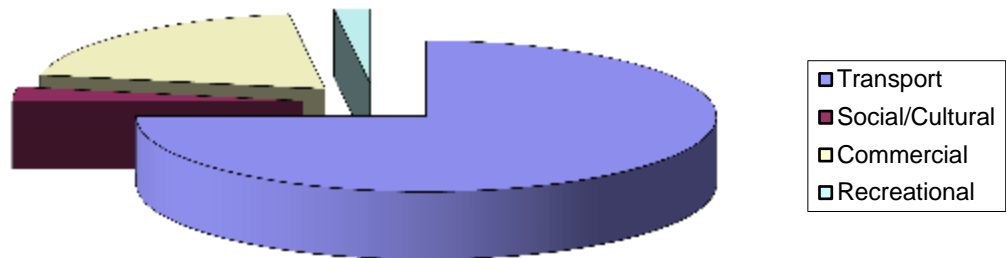


Figure 7-4. Street Purpose Distribution of an Archetypal Conventional Arterial Street

Egregious Example of Conventional Arterial Street Purposes (Illustrative): "Traffic Sewer"?

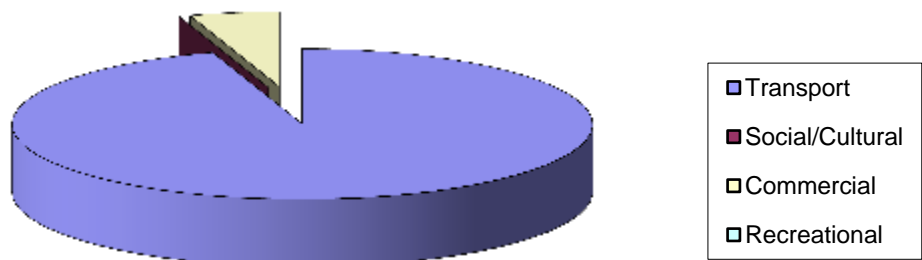


Figure 7-5. Street Purpose Distribution of an Archetypal Traffic Sewer Arterial Street

The research findings provide strong evidence that some specific aspects of street design do matter in terms of street activity and sustainability. The most striking aspect is allocation of right-of-way to pedestrians and bicyclists and away from motor vehicle travel. Each of the two test streets each had the highest proportion of right-of-way dedicated to non-motorized modes of travel while having the highest level of non-motorized travel and pedestrian social interaction in their respective cohorts. Each of the test streets also had the fewest or tied for the fewest travel lanes in their respective street section cohorts. Further, both also had far fewer commercial driveways per mile, thus far lower potential for motor vehicle intrusion into the pedestrian way than was the case with the four control streets.

King Street – The Embarcadero, the only street section among the six studied with continuous bicycle lanes in both directions, also had the highest bicycle volumes. One of the most dramatic contrasts revealed by this research was in the amount of cycling on the two streets with the highest motor vehicle volumes. Nearly twenty times more people bicycled along or to/from King Street – The Embarcadero than was the case for Lombard Street. While the former street is a link between a bicycle-friendly commuter rail line and downtown San Francisco’s Financial District, the latter is proximate to an important and bicycle-friendly employment, recreational, and cultural center, the Presidio⁹⁸. What differentiates these two streets for cycling is that King Street – The Embarcadero is far safer and more comfortable for cycling than is Lombard Street.

Street user’s survey and focus group comments reflected the importance of “physical and regulatory provision” in favor of pedestrians and non-motorized modes of travel generally. One King Street – The Embarcadero survey respondent liked its “wide median with streetcar, wide sidewalk”, as well as “the bike lane”. A focus group participant noted that it was “incredibly easy to cross Castro Street.” A Castro Street user’s survey respondent wrote admiringly that “the sidewalks are wide and there is just one lane of traffic each way”.

What are “complete streets” and how can “completeness” be measured?

LaPlante and McCann (2008) define a complete street as “a road that is designed to be safe for drivers, bicyclists, transit vehicles and users, and pedestrians

⁹⁸ The Presidio is a former military base close to the western reach of Lombard Street that has been undergoing re-development since 1996 as a major employment, cultural, and recreational area. More information can be retrieved from the Presidio web site: <http://www.presidio.gov/>

of all ages and abilities” (p. 24). Figure 6 shows such a street. While design features for complete streets may vary depending on street context, “a complete street policy is aimed at producing roads that are safe and convenient for all users” (McCann, 2005, p. 18). One measure of street completeness is allocation of right-of-way to various uses, not simply for motor vehicle passage but also for pedestrians, bicycles, and public transport. Other measures are the provision for safe pedestrian crossings and street design to moderate the speed of motor vehicles.



Figure 7-6. “Complete” King Street – The Embarcadero
Photograph by the author.

This research presents compelling evidence that complete streets contribute to street activity and sustainability. The continuous bicycle lanes, wide, multipurpose sidewalks,, and light rail along King Street – The Embarcadero, the exemplary “complete street” in this research, foster travel on foot, by bicycle, and on public transport. Just over one-quarter of the right-of-way on this street section is dedicated to non-motorized travel and nearly one-fifth has been given over to public transport. On each of the two control streets in the Big City cohort, a combined total of one-fifth or less of street right-of-way is reserved for use of pedestrians, bicyclists, and public transport patrons. While less than two-fifths of street right-of-way is allocated

to motor vehicle travel on King Street – The Embarcadero, just over three-quarters of Lombard Street’s right-of-way is available for motor vehicle movement. This is a dramatic difference and is reflected in the comments by survey and focus group participants.

Even without bicycle lanes or light rail within its cross-section, the Small City test street, Castro Street, has about 44% of its right-of-way allocated solely for uses other than moving motor vehicles. This is a proportion of space from 23% to 45% greater than that allocated for these other uses on either San Carlos Avenue or California Avenue, the two control street sections in the Small City cohort. One San Carlos Avenue focus group discussant articulated the implicit message conveyed in an unbalanced use of street right-of-way as follows: “You think about how much of a street goes toward cars versus pedestrians; when the sidewalk is really narrow as a pedestrian you kind of feel like ‘we’re not very important here.’”

To what extent does dedicated space for pedestrians, cyclists, and public transport users contribute to the amount of walking, bicycling, and public transport use along streets?

There is a formidable literature that concludes, *ceteris paribus*, the amount of walking the people do is positively associated with facilities available for walking (Frank & Engelke, 2001; Landis et al., 2001; Cervero & Duncan, 2003; de Bourdeudhuij et al., 2003; Giles-Corti & Donovan, 2003; Shay et al., 2003; Troped et al., 2003; Boarnet, et al, 2005; Forsyth et al., 2008; McCormack et al., 2008; Sallis, 2009). There have been similar findings with respect to the presence, quality, and connectivity of bicycle facilities and the actual amount of cycling observed (Nelson & Allen, 1997; Dill, 2003; Titse et al., 2005; Hunt & Abraham, 2007; Wardman et al., 2007; Dill (2009).

This research confirmed the importance of providing space on arterial streets for pedestrians, cyclists, and transit users. The two test streets devoted in proportion about one-quarter more right-of-way space to pedestrian use than did the four control streets. In comparison, the median value of the total number of pedestrians using the right-of-way of the two exemplary streets for moving, standing, or sitting was two and a half times that of the four control streets. Further, the median value for pedestrian interactions on the two test streets was three times that of the control streets. The rank order correlation between number of pedestrians sitting or standing on the six streets and the right-of-way reserved for pedestrians was a perfect 1.0. The

p-value of the rank order correlation of both total number of pedestrians and pedestrian interactions with right-of-way dedicated to pedestrian use was .07, significant at the .10 level but not at the .05 level. The main discordance in these ranks took place in the case of The Alameda, a street with the highest proportion of vacant building space along the street front, which ranked fourth in right-of-way provision to pedestrians but last in both total pedestrian volumes and pedestrian interactions. In the case of The Alameda, the street's wide, shady sidewalks survived from an earlier, more pedestrian friendly era, but some of the store fronts were shuttered, thus reducing opportunities for light spill and natural surveillance from activity rooms within buildings.

The p-value for the rank order correlation of right-of-way space dedicated to use by non-motorized modes and number of bicycles using a street was .07, thus also significant at the .10 level but not at .05. In this case the principal discordant note was sounded on Castro Street, a street with sidewalks often crowded with people walking to and from restaurants and shops. While Castro Street ranked second in proportion of right-of-way allocated to pedestrian use, legally and practically bicyclists cannot use the sidewalks because of high pedestrian volumes. Moreover, as the Castro Street section also lacks bicycle lanes or wide curb lanes, it ranks only fourth among the six streets in number of people cycling along its reach. Since Castro Street is embedded in a street grid, bicyclists can access destinations on the street as well as the adjacent Mountain View Transit Center via less crowded local parallel and cross streets. The importance of dedicated cycling facilities is shown on King Street – The Embarcadero, without question the busiest of the six street sections for bicycling. This street is the only one of the six that had continuous bicycle lanes on it in both directions along with wide sidewalks for joint use with pedestrians and without question the busiest for bicycling.

King Street – The Embarcadero was also the only street that offered continuous, dedicated space for public transport operations. As in the case with bicycle volumes, this street had by far the greatest public transport patronage. Street users commented favorably about the allocation of space to cycling, walking, and public transport along King Street – The Embarcadero by endorsing its “wide sidewalks, rail transit” and “wide median with streetcar, wide sidewalk”

What is the relationship, if any, between “space for nature” and the transport and other functions of streets?

There is both recent and older empirical evidence that the presence of street trees influences pedestrian route choice in favor of tree-lined streets (Foltête & Piombini, 2007), fosters sociable feelings among pedestrians (Sheets (1991), positively influences preference for one transit stop over another (Ewing, 2001b), and has a beneficial economic impact (Wolf, 2003). There is also evidence that there is a preference for urban scenes that include trees and other natural landscape to scenes that lack these amenities (Ulrich, 1996). Nevertheless, my research found no evidence that tree canopy *per se* or trees as buffers protecting pedestrians from moving motor vehicles was associated with use of streets by pedestrians, bicycles, or public transport patrons.

As focus group comments, the experience of most people as pedestrians, and the literature all suggest that people value street trees, there must be other factors at work that can override the presence (or absence) of trees on a street. These factors are discussed later in this chapter, as part of a framework or model of primary, secondary, and tertiary influences on or supports of the activity and sustainability of arterial streets. In short, while trees undoubtedly do add value to a street user's experience, factors like street design, street land use, transit capacity serving a street, and space reserved for pedestrians and bicyclists are likely to be much more powerful drivers of street activity and sustainability.

How does a street's aesthetic appeal affect street use, if at all?

Aesthetics appear to matter to street users. Street design quality has been found to increase shop rents and property values in Britain (Commission for Architecture and the Built Environment, 2007). The amount of active travel, especially on foot, is positively influenced by or associated with “quality of the walking environment” (Greenwald, 2003), “enjoyable scenery” (Troped, 2003), and “aesthetic appeal” (Day et al, 2006).

Research findings from this dissertation revealed a strong association between perceptions of the attractiveness of a street and both pedestrian activity and pedestrian presence on a street. The two test streets together, both with comparatively high levels of pedestrian use, were deemed by street users to be more attractive than the four control streets. This finding was significant to a p-value of well below .01. Results for the visual assessment exercise conducted as part of this

research were also favorable to the test streets, but not as decisively. Castro Street was deemed to be more visually attractive than either one of its Small City control streets within a significance level of $\alpha = .05$. King Street – The Embarcadero was tied with The Alameda as the most visually attractive Big City street, although statistically significantly more attractive at $\alpha = .05$ than Lombard Street. \

Some aspects of the aesthetic attractiveness of Castro Street were summed up by this street user's survey comment: "The fine grain of the buildings; the variety of architectural styles; buildings that come right to the sidewalk and have windows giving a view to what's inside; all of that makes it interesting to stroll along Castro." Another added a note of appreciation that the streetscape had "quite a few trees and other plants". King Street – The Embarcadero business survey respondents praised the "beautiful - water views, Muni line design, palm trees" and the "open, airy, clean feel" of the street, as well as the "water view" offered along its reach. Similarly, King Street – The Embarcadero street user's survey respondents liked the "beautiful water views, Muni line design, palm trees" and "open, airy, clean feel; streetcar access; water view".

"Sustainable" streets.

To what extent can the "sustainability" of urban commercial streets be assessed?

As discussed in Chapter 2, in recent years several notable sets of indicators of the degree of sustainability and/or the multi-use nature of arterial streets have been proposed (Ribeiro & da Costa, 2004; Porta & Renne, 2005; Jones, et al., 2007a; Lillebye, 2007; Dowling & Reinke, 2008; and Mehta, 2006). This research consulted these sources and others in the scholarly literature in creating a set of metrics for the assessment of arterial street activity and sustainability. The most important of these metrics were the following:

- Number of pedestrians moving, sitting, or standing;
- Pedestrian interactions;
- Bicyclists along and to/from the street;
- Public transport boardings;
- Right-of-way space allocation by purpose;
- Proportions of pervious surface area and tree canopy;
- Crash statistics; and

- Street user's and business surveys results.

I derived qualitative meaning and texture from focus group conversations for comparison to the quantitative findings.

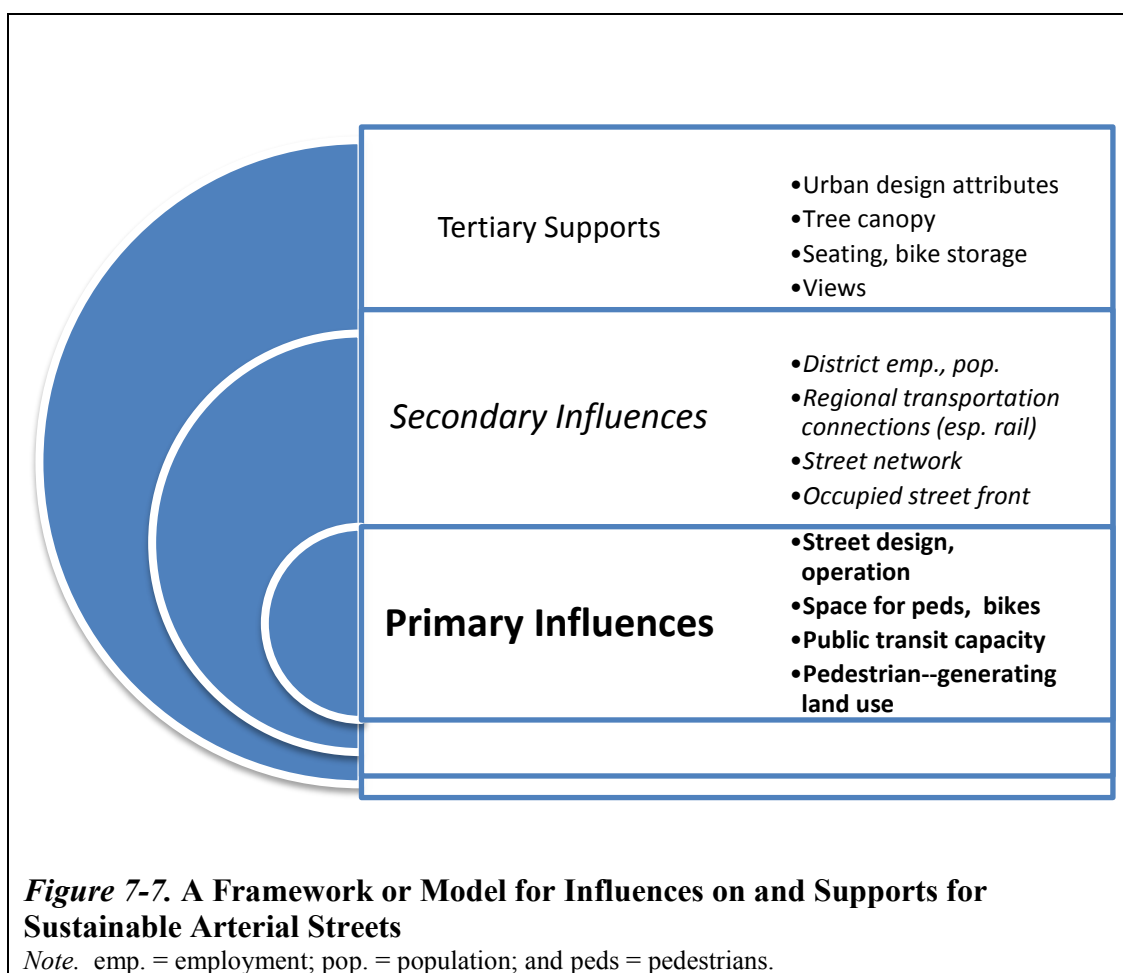
I developed two indices for assessment of street traffic safety for non-motorized travel modes: the Comparative Pedestrian Safety Index and the Comparative Bicycle Safety Index. I also created two other indices to measure street activity and sustainability: the Ratio of Drivers to People out of Motor Vehicles and the Ratio of Drivers to Transit Boardings. All four of these assessment indices are original contributions of this research. Chapter 5 provides comprehensive details on assessment findings as well as summary “traffic signal” and “Olympic medal” matrices for snapshot appraisal of results.

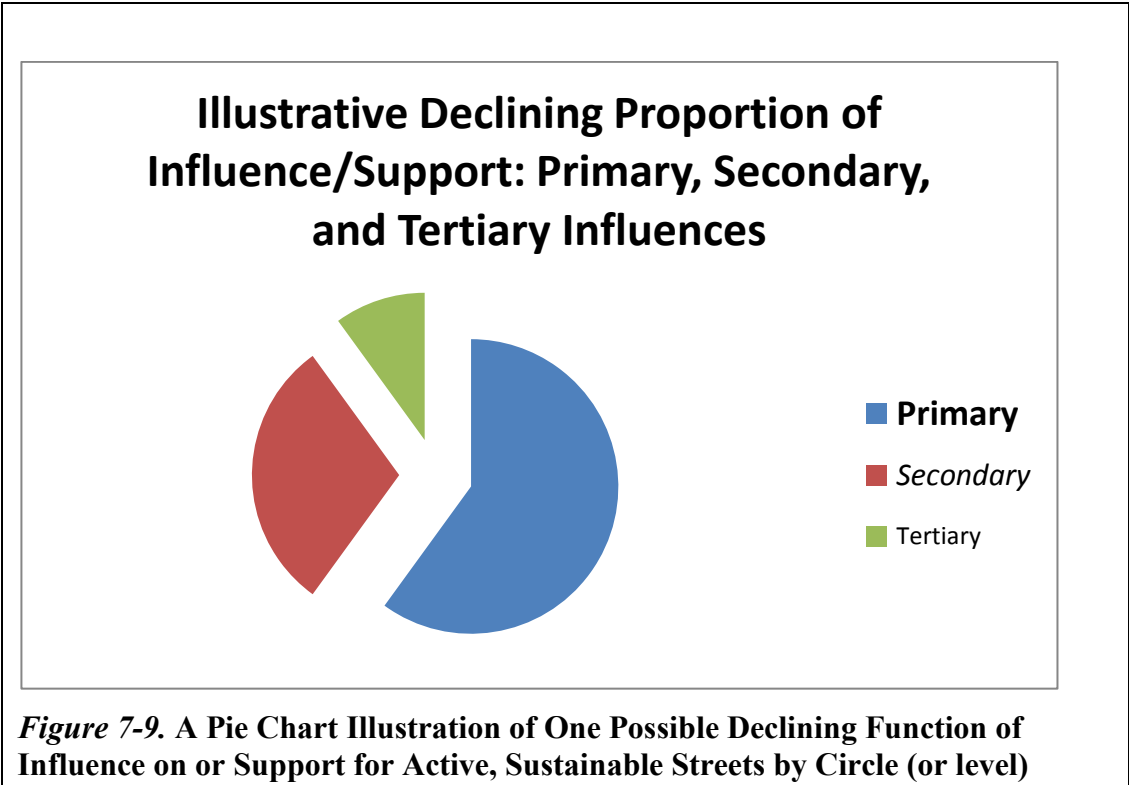
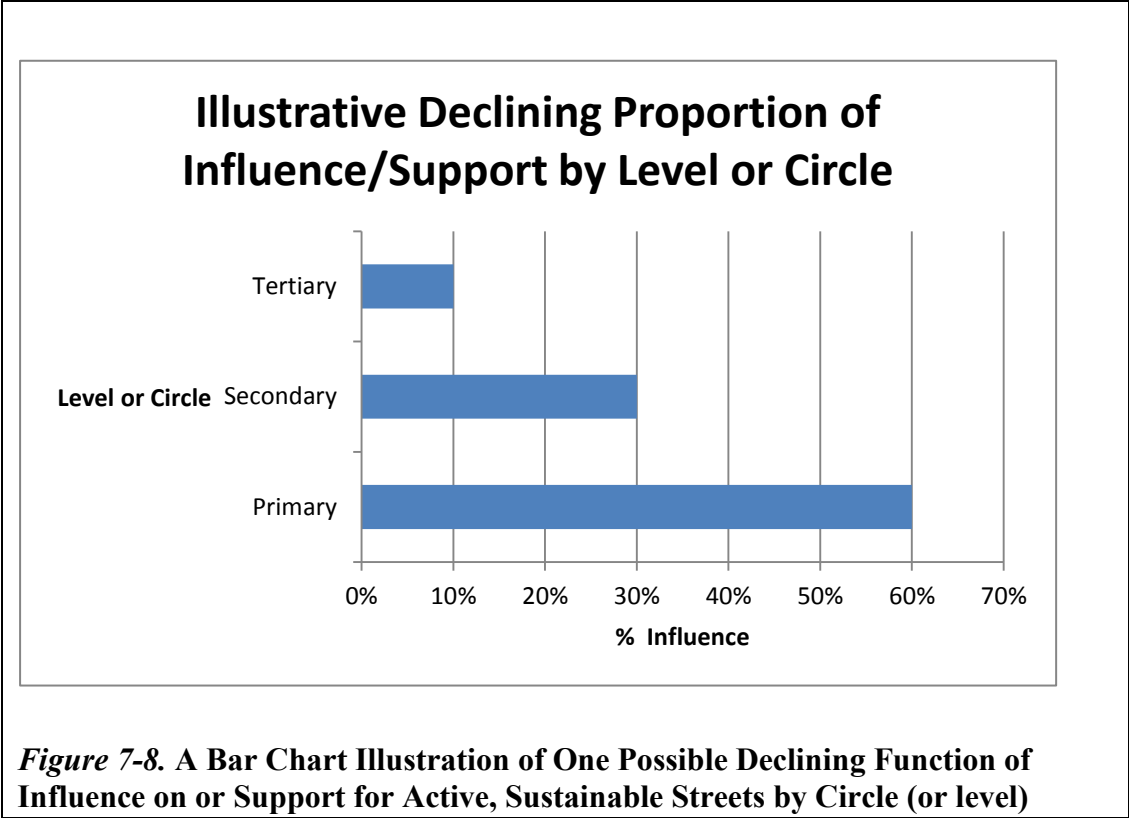
Figure 7 displays a model or framework for the influences on and supports for active, sustainable arterial streets. I have formulated this model through a distillation of research results from this dissertation and findings of the scholarly literature. There are three circles of influence or support. The inner circle, metaphorically akin to the bull's-eye on a target used for archery or pistol shooting practice, contains the primary influences. The next circle encompasses weaker, secondary influences. Within the third, outer circle are still weaker factors that serve to support or enhance the influence of the primary and secondary factors.

The primary or first circle influences include street design and operations (number of motor vehicle travel lanes, amount of space and separation from moving vehicles given to pedestrians and bicycles, intersection crossing treatments, number of commercial driveways, and traffic control devices), pedestrian-generating land uses and public transport capacity to serve a street. The secondary circle influences are employment and population density in the district surrounding a street, regional rail and other regional transportation connections, the surrounding street network, and the amount of occupied street frontage. The third circle factors consist of such urban design attributes as extent of continuous street frontage or street wall, number of windows and doors fronting a street and quality of street lighting and street furniture. Other tertiary, support factors are the amount of tree canopy and permeable surface, the extent of pedestrian seating and bicycle storage available, and the views afforded from different locations along the street.

While it is not possible with any extant research findings to quantify the degree (or the coefficient, if you will) of influence or support for factors within each

of the circles, it appears likely that there is a geometric decline as one moves outward from the first circle. That would explain why factors such as tree canopy and fine-grained urban design attributes are overcome by other factors like street design and street land use. The tertiary factors can contribute to the success of but cannot replace the primary or even secondary factors. Figures 8 and 9 illustrate in horizontal bar chart and pie chart forms one possible declining function of influence on or support for active, sustainable streets by the circles depicted in Figure 7.





The composition of each of the three circles, as well as suppositions about decreasing influence or support will require empirical validation in future research.

There will of course most likely be variations case by case. There are other factors not included in any of the three circles presented above. These include topography, climate, labor force participation as it affects daily travel (Levinson & Kuman, 1995; Srinivasan, McGuckin, & Murakami, 2006), the transport policies pursued by cities and nations (Rietveld, & Daniel, 2004; Pucher, & Buehler 2008); and cultural attitudes. These are all subject to great variation from place to place and are largely outside of the control of planners working at the level of an arterial street corridor. These exogenous factors also require further research as they pertain to street use.

Contributions to New Knowledge

While matched pair study designs are not uncommon in transport and urban planning research, this dissertation is the first research to apply a mixed-methods approach to comprehensive assessment of active, sustainable arterial streets using a 1:2 matched pair study design. This has facilitated study in depth of an exemplary commercial arterial street in comparison to two otherwise similar control streets in each of two city size categories. This approach was supported by the most extensive, interdisciplinary literature review yet undertaken of research pertaining to the nature and determinants of active, sustainable arterial streets. The validity of findings from this research was strengthened by the triangulation of research methods. These findings included quantitative (descriptive and non-parametric statistics) and qualitative (street user's surveys, business surveys, focus groups, and visual assessment surveys) research undertaken in this dissertation. The third method was an exploration of prior research results.

This research also produced a variety of original tools for the assessment of active, sustainable arterial streets. These include the following:

- A typology for measuring allocation or apportionment of street right-of-way by purpose;
- Protocols and metrics for measuring pedestrian activity and presence, as well as bicycle use;
- The Comparative Pedestrian Safety Index;
- The Comparative Bicycle Safety Index;
- The Ratio of Drivers to People Out of Motor Vehicles; and
- The Ratio of Drivers to Public Transit Boardings.

The latter two ratios compare to the movement efficiency indicator, the ratio of people moving to vehicles moving on a street segment (Marshall et al. 2004), as proposed in the ARTISTS project. The first, however, more directly addresses the level of street activation provided by pedestrians and cyclists. The second is a more direct comparison of car dependence to transit dependence.

An early product of this research was a working definition of a sustainable arterial street. This definition, formulated during the literature review and revealed to be robust throughout the course of the scholarly investigation, is as follows: “A sustainable arterial street gives priority to energy efficient, low or no emission modes of transport; supports social and economic vitality; ensures traffic and social safety; incorporates natural elements; and creates visual interest for its users.” This definition built upon as well as adds texture to two earlier attempts discussed previously in this dissertation to define a “sustainable arterial street” (Marshall, Jones, & Plowright, 2004) or just “sustainable street” (Greenberg, 2008). While both were notable, neither conveyed the multi-functional role of such streets in expressing all the dimensions of sustainability.

Another important and original finding is the apparent gap between perceptions of street safety and objective information about traffic safety on arterial streets. As discussed in the concluding section of this chapter, further research is needed to inform understanding of this phenomenon. There is very little in the transport planning, urban planning, traffic engineering, or public health literatures at present to illuminate this subject.

While perhaps not original, this dissertation adapted for more extensive use than ever before in a scholarly work, “traffic signal” matrices for comprehensive, comparative assessment of the performance of streets across many attributes of activity and sustainability. The virtues of these matrices are they are both comprehensive and comprehensible at a glance.

Another notable contribution of this dissertation is the distillation of findings in A Framework or Model for Influences on and Supports for Sustainable Arterial Streets. The model was informed by findings from this research that reveal the primary importance of street design, provision of space for pedestrians and cyclists, public transport capacity, and pedestrian-oriented land uses in creating active, sustainable streets. It is important to note that car-generating land uses are not listed as influences on, much less supports, of active and sustainable arterial streets. These

land uses do not necessarily preclude active, sustainable arterial streets. All depends on how motor vehicle trip generation is managed, including access management, parking placement, intersection control, street cross-section design, and related measures. In contrast, pedestrian-generating land uses by their nature activate streets toward sustainability. Land use interacts with physical provisions and other variables to help shape street use.

Most ideas have precursors and this one is no exception. Most influential for me was the work of Ewing (1996) in delineating three categories of influence on transit-friendly urban design: “essential”, “highly desirable”, and “nice additions”. There are two important distinctions between the framework or model proposed in this dissertation and Ewing’s three categories of transit-friendliness. The first and most obvious is that the model or framework presented here is suited for assessment of influences on how active and sustainable are any given arterial streets. The second is that the sustainable arterial streets circles of influence have distinct geographic scales ranging from the street-level to the neighborhood or district environs of the street, thence to the wider metropolitan area.

Active and sustainable arterial streets, like all complex phenomena, are difficult to describe with any limited set of variables. This problem is acute for arterial streets, which by definition are connected to “everything else” as well as residing at the metaphorical junction between human behavior and the physical world. Nevertheless, I believe that the twelve variables that inhabit the three circles of influences on and supports for arterial street activity and sustainability are the most salient to operationalize for assessment purposes. Their selection and placement derive from the mixed-methods findings of this dissertation, a comprehensive review of the scholarly and practitioner literature, and my own extensive experience as an urban transport planner.

The space syntax researchers, including Jiang and Liu (2009), Bafna (2003), Penn (2003), and others, look to network configuration for answers about the significance of streets. Their work is rigorous and valuable in abstracting from complex reality a powerful model of causation. At the same time, however, the space syntax scholars also strip away much of the meaning as well as purpose of the street in urban life. Surely Jan Gehl (2006) is right in describing a city’s streets as its essence. Just as cities are complex socio-economic and physical entities, so are their streets. A reductionist view of streets as one-dimensional links in a vast urban fence

abstracts from rather than explores this complexity. Location, the heart of the space syntax network determinism, does influence street use. Nevertheless, there is an array of other powerful and distinct attributes that influence the choice of one street over another by individuals. The richness of this array and how this complexity differentiates one street from another was explored in the literature review as well as in the empirical work for this dissertation.

Even this dissertation, comprehensive as it was, did not have the scope to investigate in detail some important aspects of sustainability. Carbon emissions, resource consumption, economic performance, and social capital, all important for sustainability, were assessed through use of proxies such as motor vehicle traffic volume, motor vehicle speed, use of alternatives to the private motor vehicle, and pedestrian activity. Future research will need to cover the former set of topics directly.

These last pages of the last chapter are a good time to return to the big, overarching questions posed in Chapter 2. Can arterial streets be designed or redesigned to become economically, socially and environmentally sustainable, livable, active, and attractive places for people and communities? How then to measure and achieve such an enterprise? What are the key elements in an endeavor to make arterial streets perform as both “passage and place”? What works, what does not; what is important, what is not? This research and that of other scholars give a resounding affirmation to the feasibility of designing active, sustainable arterial streets. Similarly, my research and the research of other specialists show how to create and access such streets as both travel links and community places.

Guideposts for Future Research

This research has yielded a wide array of findings that illuminate the nature of active, sustainable, complete, and context sensitive streets. Nevertheless, there is a need for similar research, but on larger samples of streets, in more geographic areas in North America and internationally. As discussed previously, further study is also called for on the gap between subjective views on perceived safety and objective data on safety.

Moreover, additional work at a high level of resolution is required on how streetscape, urban design, and provision for nature influence, or support, street use. One promising approach would be to compare streets that have similarly strong building blocks in place regarding the primary and secondary influences on street

activity and sustainability shown in Figure 7, but vary greatly in urban design quality or provision for nature, or both. A similar approach could be taken to study the differential impact of population and/or employment density, as well as for more land use categories than treated in this research, on the degree to which streets are active and sustainable.

More research is needed as well on the differential impact on street sustainability of several variables not studied in this dissertation. These variables include pedestrian signal crossing time allocated at intersections, traffic noise, air quality on street level, as well as comparative travel times along streets for pedestrians, cyclists, public transport, and private motor vehicles. Hedonic pricing studies of the differential effect of sustainably designed streets on real property valuations, rental prices, and/or retail sales would be helpful in illuminating economic effects. A detailed appraisal of the role of parking in influencing the activity on and sustainability of commercial arterial streets may also help fill in a fuller picture. The same might be said for access management or controlling the number and placement of driveways along an arterial street.

There is also scope for further development of research methods used in this dissertation. This includes taking focus groups on walking tours of a street before or even during the focus group session, use of digitized video for counting pedestrians and cyclists, and refinements in measurement of tree canopy.

Additional research is also needed to better understand the relationship and importance of various street design elements to street sustainability. These elements include exclusive public transport rights-of-way or travel lanes, continuous bicycle lanes, roundabouts, angle compared to parallel parking, raised center medians protecting pedestrian crossings and intersection bulb-outs or extended curbs.

Natural experiments are needed to enrich the study of determinants of active, sustainable arterial streets. Road diets are planned for two of the six streets in this research, The Alameda and California Avenue. Since a before and after research approach holds many variables constant, this type of inquiry can result in valuable insights into determinants of change.

Finally, greater understanding is needed of the unique contributions to sustainability and activity of pedestrian-only streets. The evolution described in these pages of The Embarcadero Freeway to the complete street that is King Street – The Embarcadero now and from the conventional post-World War II four-lane Castro

Street to today's context sensitive two-lane Castro Street is suggestive of the importance that making room for pedestrians has in creating active, sustainable streets. Pedestrian streets with nearby, high capacity public transport and parallel bicycle-friendly routes may offer opportunities for even further progress toward more active, more sustainable communities. Research to explore the effects of these streets is a logical next step in the scholarship on sustainable streets.

The ultimate purpose of research into active, sustainable streets is to inform professional practice in the street planning and design. The design professionals at the streets of clay potter's wheel (so to speak) need guidance about what works and what does not, what is important and what is not, and in which circumstances. Street planning, like much of the rest of transport planning, is evolving into a holistic practice. The focus is shifting away from serving the motor vehicle first and foremost to serving people and communities, including those who are or could be spending time on a street out of a motor vehicle. I earnestly hope that this and future research like it will help to move professional practice even further in this beneficial direction. This direction is, to recall the words of Jane Jacobs (1961), that in which designers make sure to "give room to other necessary and desired city uses that happen to be in competition with automobile traffic needs" (p. 363).

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APPENDICES

Appendix A

Photographs for visual assessment.

Small city photos 1-6.



Small city photos 6-12.



Big city photos 1-6.



Big city photos 7-12.



Appendix B

Selected community discussion, association and newspaper sites.

Mountain View.

Mountain View Voice -

<http://www.mv-voice.com/>

Old Mountain View Neighborhood Association -

<http://www.omvna.org/>

http://groups.yahoo.com/group/old_mountain_view_west_na/

Palo Alto.

College Terrace Residents' Association -

<http://www.ctra.org/CTRA/Home.html>

Evergreen Park Neighborhood Association -

<http://www.epna.palo-alto.ca.us/>

<http://groups.yahoo.com/group/evergreen-park-announce/>

Midtown Residents Association -

<http://www.mimi.com/mra/>

<http://groups.yahoo.com/group/PaloAltoMidtown/>

Palo Alto Online –

<http://www.paloaltoonline.com/>

San Carlos.

San Mateo County Times -

<http://www.mercurynews.com/san-mateo-county>

San Mateo Daily Journal -

<http://www.smdailyjournal.com/>

San Francisco.

Cow Hollow Association -

<http://www.cowhollowassociation.org/>

District 6 -

<http://groups.yahoo.com/group/District6inSF/>

Marina Times –

http://www.marinatimes.com/nov10/comm_mca.html

San Francisco Marina Community Association -

<http://www.sfmca.org/>

San Jose.

Rose Garden Neighborhood Preservation Association -

<http://rgnpa.org/home.html>

Shasta Hanchett Neighborhood Association -

Shasta_Hanchett_Talk@yahoogroups.com

<http://www.shpna.org/>

Appendix C

Streets of Clay Surveymonkey survey and street research blog sites.

Surveymonkey.

California Avenue.

<http://www.surveymonkey.com/s/LDPD2LX>

<http://www.surveymonkey.com/s/LCJNXGP>

Castro Street.

<http://www.surveymonkey.com/s/7CMCV72>

<http://www.surveymonkey.com/s/LJ2DD23>

King Street – The Embarcadero.

<http://www.surveymonkey.com/s/YNZZSW5>

<http://www.surveymonkey.com/s/QFH8DSY>

Lombard Street.

<http://www.surveymonkey.com/s/7J3WL8Y>

<http://www.surveymonkey.com/s/7XY7TDF>

San Carlos Avenue.

<http://www.surveymonkey.com/s/75G8HCT>

<http://www.surveymonkey.com/s/7NX5C37>

The Alameda.

<http://www.surveymonkey.com/s/7GKYQS9>

<http://www.surveymonkey.com/s/9LRFW2S>

Blogs.

California Avenue.

<http://calavestreetusers.blogspot.com/>

Castro Street.

<http://castromvbusiness.blogspot.com/>

<http://castrostreetusers.blogspot.com/>

King Street – The Embarcadero.

<http://kingembresearch.blogspot.com/>

<http://sustainablesfstreets.blogspot.com/>

Lombard Street.

<http://lombardstreetbusiness.blogspot.com/>

<http://sustainablesfstreets.blogspot.com/>

San Carlos Avenue.

<http://sancarlosaveresearch.blogspot.com/>

<http://sancarlosavenue.blogspot.com/>

The Alameda.

<http://thealamedabusiness.blogspot.com/>

<http://thealameda.blogspot.com/>

Appendix D

Focus group topics.

Most important reasons for your visit to _____ Street/Avenue

Your typical means of travel to _____ Street/Avenue

Convenience of _____ Street/Avenue

Safety of _____ Street/Avenue

Comfort of _____ Street/Avenue

Attractiveness of _____ Street/Avenue

What you like about _____ Street/Avenue

What you dislike about _____ Street/Avenue

What would make _____ Street/Avenue better

What other opinions you have about _____ Street/Avenue

Appendix E

Street user's survey instrument example.

Dear Lombard Street User,

This survey is part of the doctoral dissertation research I am conducting on the effect of street design on the use of "main streets". I would much appreciate your assistance by filling out the short questionnaire regarding your own use of and perspectives on San Francisco's Lombard Street between Fillmore and Broderick. The results will increase understanding of the use and effectiveness of Lombard Street and other "main streets".

Please feel free to contact me at sustainablestreets@gmail.com with any questions.
Thanks in advance!

Best regards,

Joe Kott

1. In which neighborhood do you reside?

- ☐ Cow Hollow ☐ Other San Francisco Neighborhood
☐ Marina District
Other (please specify)

2. How do you most frequently travel to Lombard Street (check one or more as applicable)?

- ☐ Walk ☐ Rail
☐ Drive ☐ Taxi
☐ Bicycle ☐ Ride in someone else's vehicle
☐ Bus
Other (please specify)

3. What are the most frequent reasons why you visit Lombard Street (check one or more as applicable)?

- ☐ Dining
☐ Shopping
☐ Personal services (e.g. haircut)
☐ Professional services (e.g. doctor, lawyer, realtor)

☐ Banking
Other (please specify)

4. In your opinion, how CONVENIENT is Lombard Street to use?

☐ Very
☐ Somewhat
☐ No at all
Other (please specify)

5. In your opinion, how SAFE is Lombard Street to use?

☐ Very
☐ Somewhat
☐ Not at all
Other (please specify)

6. In your opinion, how COMFORTABLE is Lombard Street to use?

☐ Very
☐ Somewhat
☐ Not at all
☐ Other

7. In your opinion, how ATTRACTIVE is Lombard Street?

☐ Very
☐ Somewhat
☐ Not at all
Other (please specify)

8. What do you LIKE about Lombard Street as a street?



9. What do you DISLIKE about Lombard Street as a street?



10. How would you IMPROVE Lombard Street as a street?



11. How active (i.e. lots or few people are on it each day) a street do you consider Lombard Street to be?

- ☐ Very active
- ☐ Somewhat active
- ☐ Not very active

Comment



12. How important is Lombard Street to you in your daily life?

- ☐ Very
- ☐ Somewhat
- ☐ Not at all

Other (please specify)

13. What other opinions do you wish to express about Lombard Street?



14. Would you be interested in participating in a follow-up focus group session and/or in-depth personal interview in connection with this research project? If you answer "yes" below, please send a note of interest to sustainablestreets@gmail.com

- ☐ Yes, the Focus Group
- ☐ Yes, the In-depth Interview
- ☐ Yes, both the Focus Group and the In-Depth Interview
- ☐ No, neither the Focus Group or the In-Depth Interview

Comment

<< Prev

Done >>

Appendix F

Business and merchant's associations.

Mountain View.

Mountain View Chamber of Commerce -

<http://chambermv.org/>

Palo Alto –

California Avenue Area Development Association –

<http://www.paloaltoonline.com/CAADA/board.html>

San Francisco.

South Beach Mission Bay Business Association -

http://www.southbeachmissionbay.com/local_business/business_association.php

The Marina Merchants Association –

<http://www.themarinastf.com/about.php>

San Jose.

The Alameda Business Association -

<http://www.the-alameda.com/>

San Carlos.

San Carlos Chamber of Commerce -

<https://www.sancarloschamber.org/default.aspx>

Appendix G

Business survey instrument example.

Dear Castro Street Business Person,

This survey is part of the doctoral dissertation research I am conducting on the effect of street design on the use of "main streets". I would much appreciate your assistance by filling out the short questionnaire regarding your own business and your perspectives on Castro Street. The results will increase understanding of the use and effectiveness of your street and other "main streets".

Please feel free to contact me at sustainablestreets@gmail.com with any questions. Thanks in advance!

Best regards,

Joe Kott

1. What is the nature of your business on Castro Street?

- | | |
|--|---|
| <input type="radio"/> Restaurant | <input type="radio"/> Real estate |
| <input type="radio"/> Retail shop | <input type="radio"/> Medical office |
| <input type="radio"/> Food store | <input type="radio"/> Legal office |
| <input type="radio"/> Personal services | <input type="radio"/> Other professional services |
| <input type="radio"/> Financial services | |

Other (please specify)

2. How long has your business been located on Castro Street?

- | | |
|--|--|
| <input type="checkbox"/> Less than 1 year | <input type="checkbox"/> Between 5 and 10 years |
| <input type="checkbox"/> Between 1 and 3 years | <input type="checkbox"/> Between 10 and 20 years |
| <input type="checkbox"/> Between 3 and 5 years | <input type="checkbox"/> More than 20 years |

3. How many employees (full-time and part-time) do you have?

4. What are your typical hours and days of business each week?

5. How would you rate Castro Street as a place to do business?

- ☐ Excellent
- ☐ Good
- ☐ Fair
- ☐ Poor
- ☐ Other

6. What do you LIKE about Castro Street as a street?



7. What do you DISLIKE about Castro Street as a street?



8. How would you IMPROVE Castro Street as a street?



9. How active (i.e. lots or few people are on it each day) a street do you consider Castro Street to be?

- ☐ How active (i.e. lots or few people are on it each day) a street do you consider Castro Street to be? Very active
- ☐ Somewhat active
- ☐ Not very active

Comment

10. What other opinions do you wish to express about Castro Street



11. Would you be interested in participating in a follow-up focus group session and/or in-depth personal interview in connection with this research project? If you answer "yes" below, please send a note of interest to sustainablestreets@gmail.com

- ☐ Yes, the Focus Group
- ☐ Yes, the In-depth Interview
- ☐ Yes, both the Focus Group and the In-Depth Interview
- ☐ No, neither the Focus Group or the In-Depth Interview

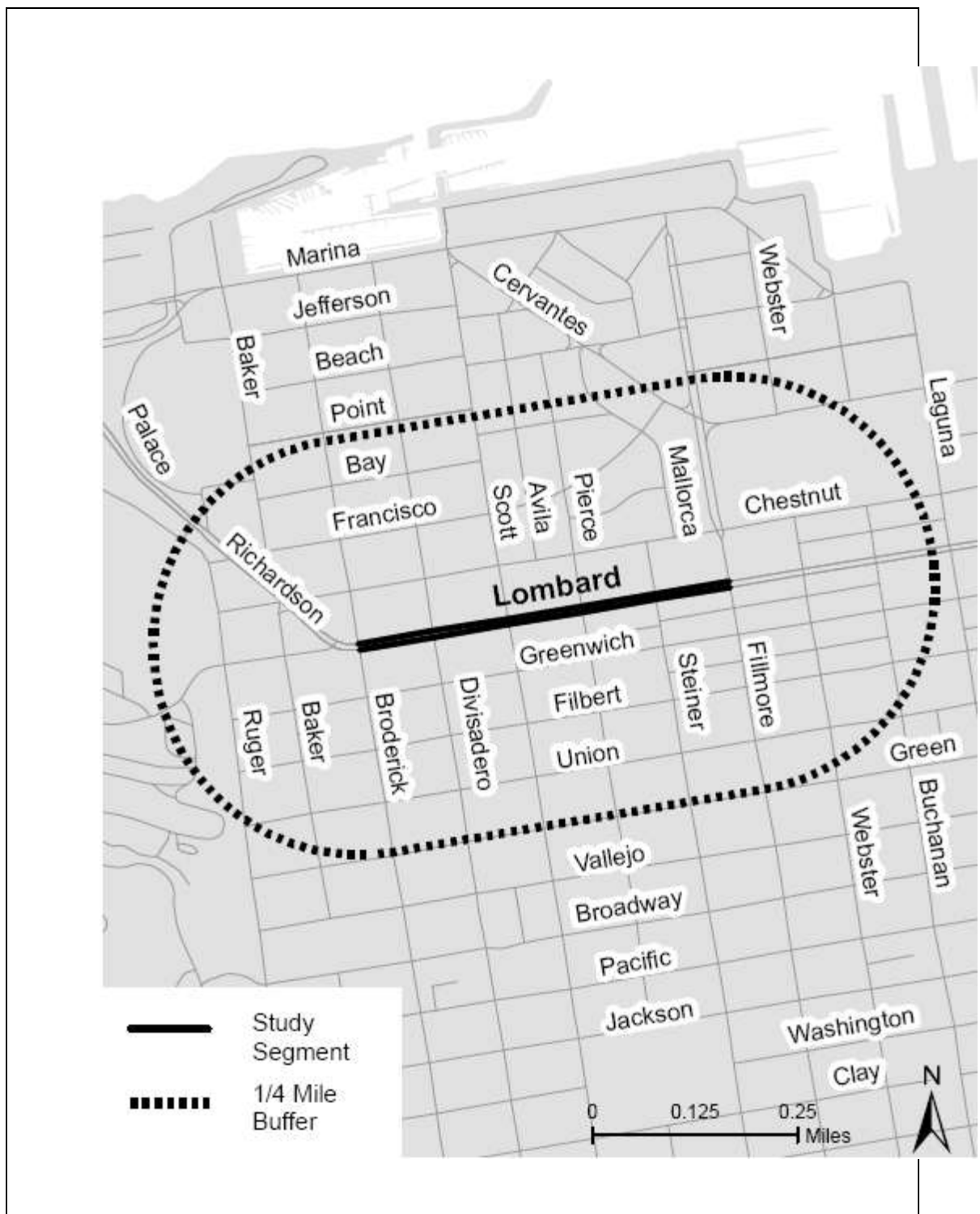
Comment

Done >>

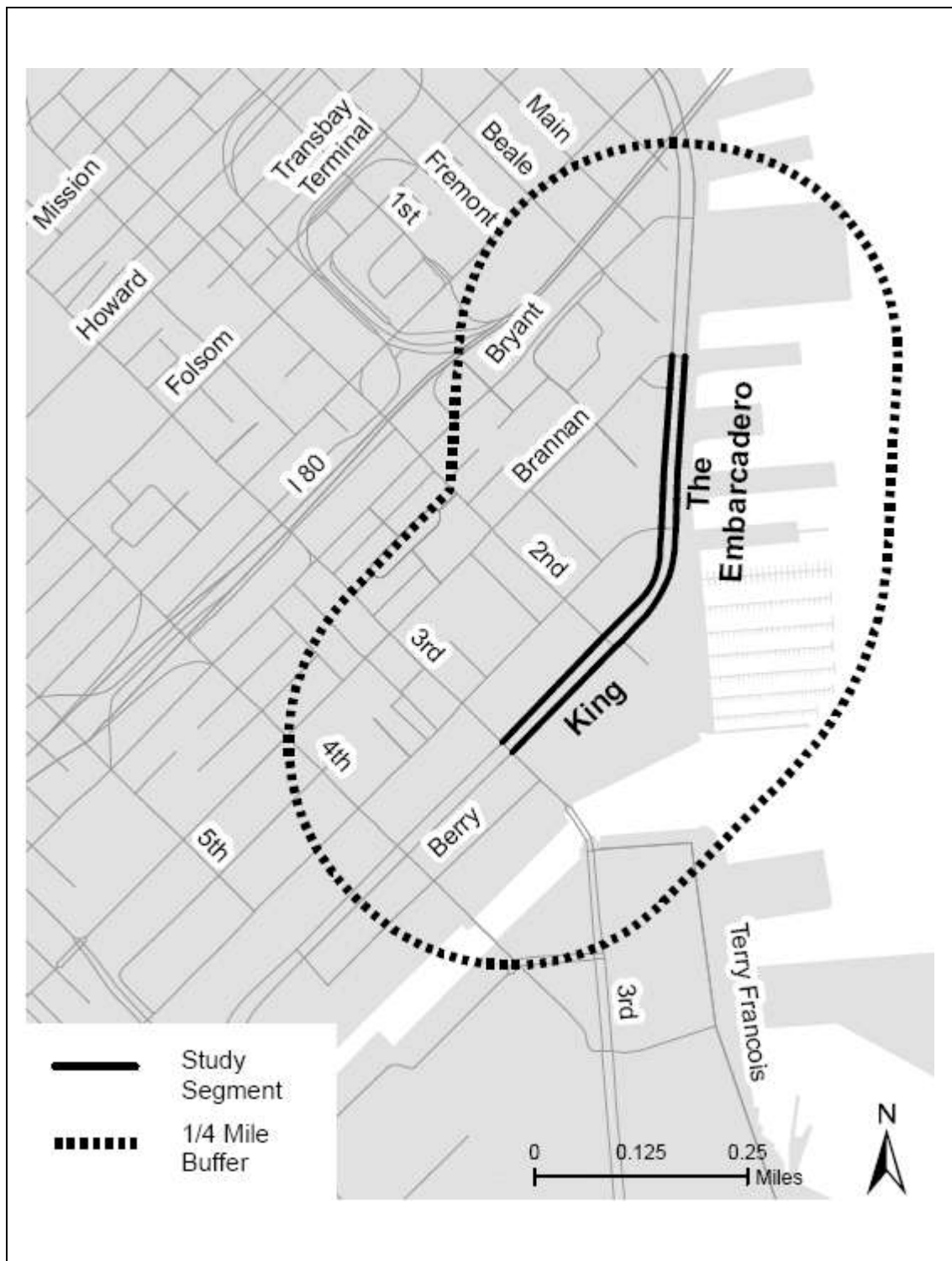
Appendix H

Map of street buffers.

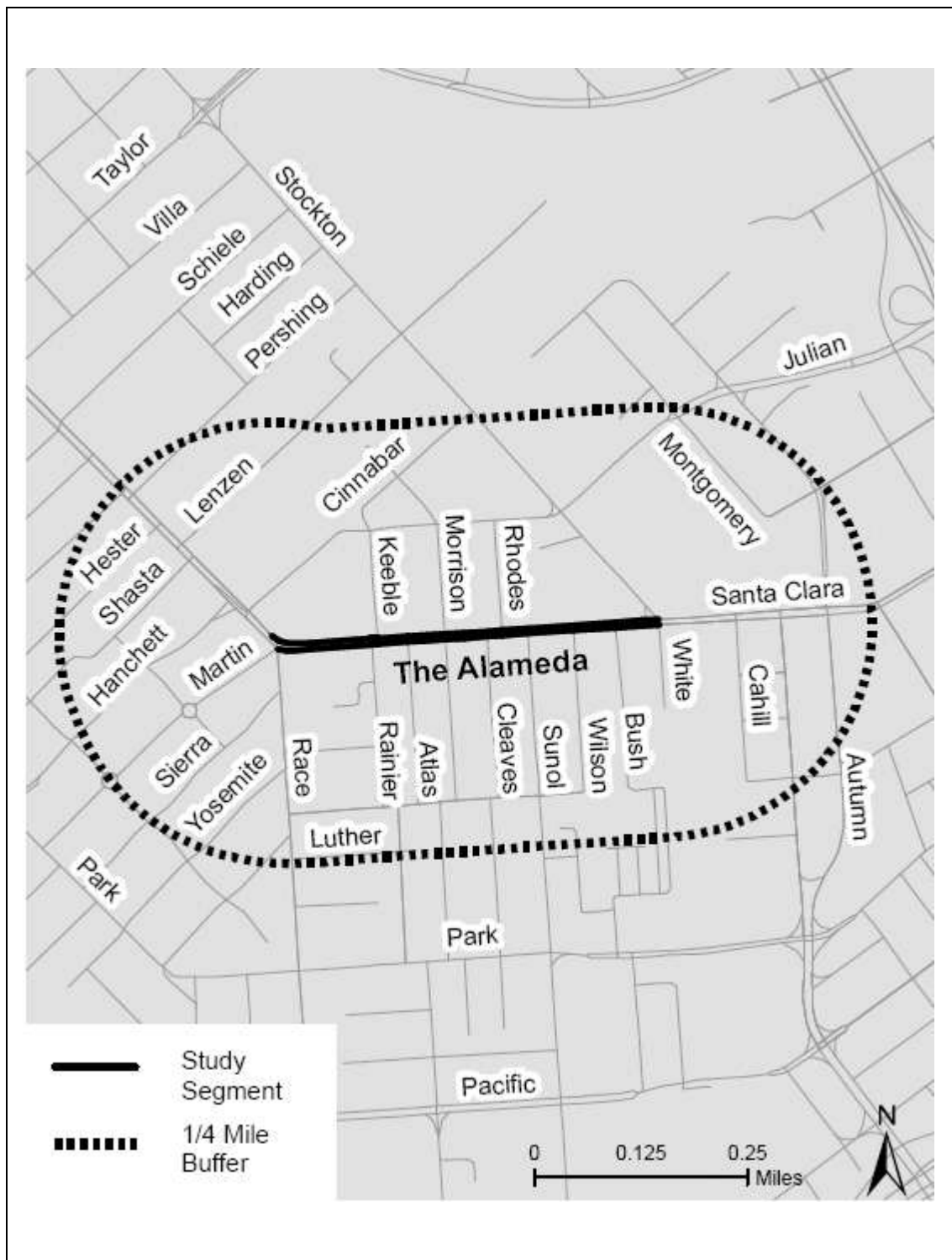
Lombard Street.



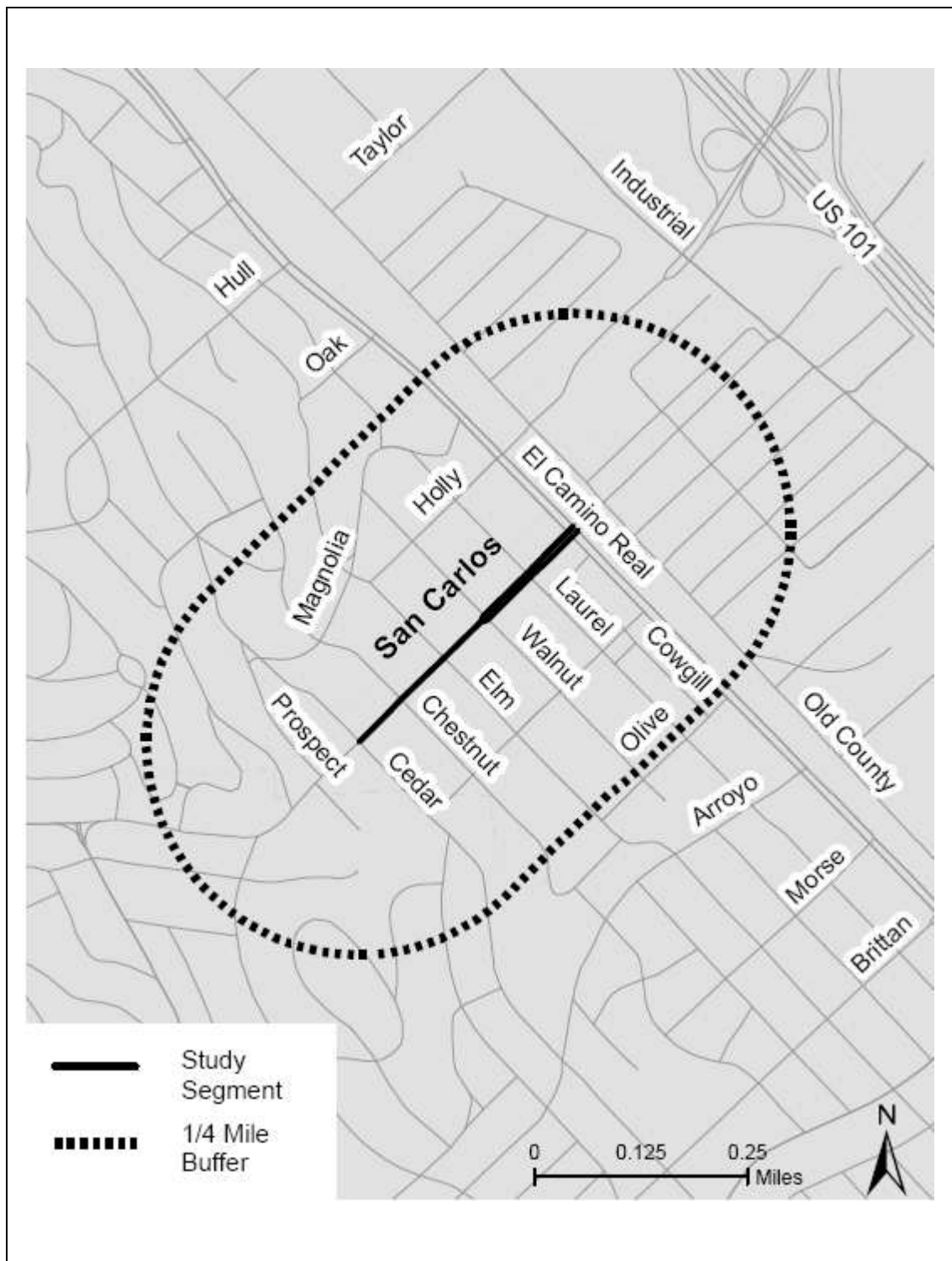
King Street – The Embarcadero.



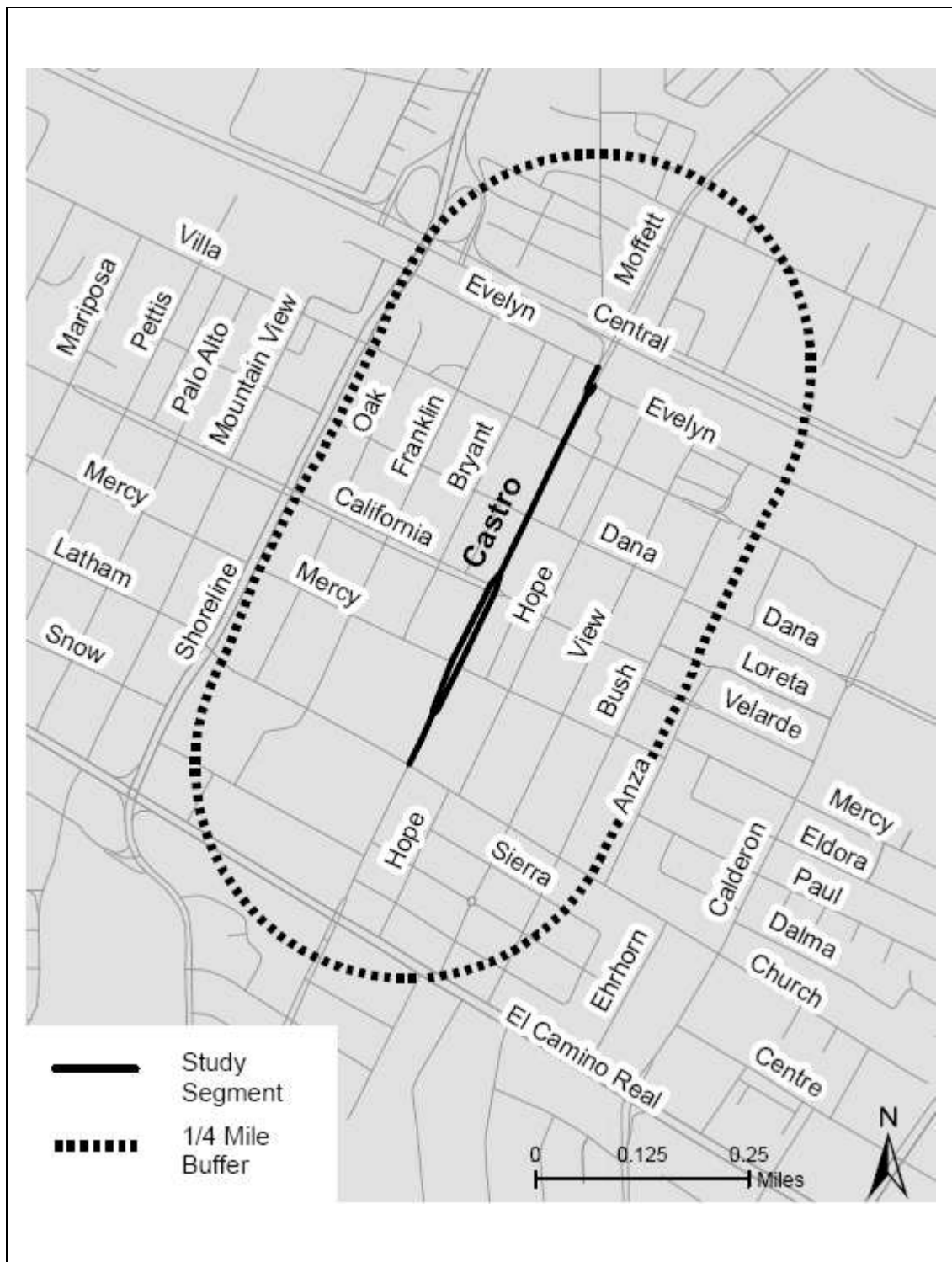
The Alameda.



San Carlos Avenue.



Castro Street.



California Avenue.

